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Debris/Ice/TPS Assessment And Integrated Photographic Analysis For Shuttle Mission STS-45

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PHOTOGRAPHIC ANALYSIS FOR SHUTTLE
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Space Administration

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ORIGINAL CONTENTS
COVER ILLUSTRATIONS

DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-45

March 24, 1992

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center (KSC) Photo/Video Analysis, reports from Johnson Space Center, Marshall Space Flight Center, and Rockwell International - Downey are also included to provide an integrated assessment of each Shuttle mission.

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Shuttle Mission STS-45 was launched at 8:13 a.m. local 3/24/92

1.0 Summary

In addition to the Debris/Ice/TPS assessment, this report provides an integrated Photographic Analysis of Shuttle Mission STS-45 with contributions from KSC, JSC, MSFC, and Rockwell - Downey.

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 22 March 1992. The detailed walkdown of Launch Pad 39A and MLP-1 also included the primary flight elements OV-104 Atlantis (11th flight), ET-44 (LWT 37), and BI-049 SRB's. There were no vehicle anomalies. Facility discrepancies were worked real-time and no items were entered into OMI S0007, Appendix K, for resolution prior to vehicle tanking.

The vehicle was cryoloaded for flight on 24 March 1992. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no ice/frost or TPS conditions outside of the established data base. The External Tank exhibited light condensate on the TPS acreage. Six Ice/Frost Team observation/anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. The LH2 umbilical leak sensor detected no significant hydrogen during the cryoload. The tubing was successfully removed from the vehicle with no TPS contact or damage.

A small amount of ice/frost had formed on the aft pyrotechnic canister bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. A 4-inch diameter ice/frost formation with venting (blowing) purge gas was present on the 17-inch flapper valve actuator access port foam plug forward (top) corner. The ice/frost formation was acceptable for launch per NSTS-08303. MPS evaluated the venting/blowing purge gas and deemed the condition acceptable for launch.

A debris inspection of Pad 39A was performed after launch. Two 11"x16" Dome Mounted Heat Shield (DMHS) thermal protection blanket sacrificial patches were found southwest of the pad. No other flight hardware, such as FRSI plugs or tiles pieces, was found. Launch damage to the holddown posts was minimal. EPON shim material on the south holddown posts was intact, but debonded. There was no visual indication of a stud hang-up on any of the south holddown posts. No frangible nut/ordnance fragments were found. The GH2 vent line had latched properly. Damage to the facility overall was minimal.

A total of 138 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. A stud hang-up occurred on HDP #4. The EPON shim material was pulled loose by the stud. Two ordnance/frangible

nut fragments fell from the HDP #7 DCS/stud hole. A 3"x0.75" debris particle appeared when the vehicle was 18 inches above the HDP shoe.

The Orbiter RH wing leading edge RCC panel #10 sustained impact damage sometime during the mission. OTV camera 066 performed a surveillance scan of the vehicle at T-1 hr 42 min and confirmed the absence of impact damage. Launch films and high speed photography showed no impacts to this area by debris, such as the OIS box found in the SSME flame trench, during liftoff. Analysis of launch still photographs and original negatives did not reveal any signs of the impacts at the time of launch. No photography was available to establish that the RCC panel impact damage had occurred during ascent, in orbit, or during re-entry.

A section of SSME Dome Mounted Heat Shield (DMHS) thermal protection blanket sacrificial patch material originated near the 9:00 position on SSME #3, fell aft near SSME #1 at T+31 seconds MET, and separated into two pieces in the SSME plume. The two SSME DMHS patches were found near the pad after launch. ET aft dome charring, plume recirculation, and SRB separation were nominal.

OV-104 was not equipped to carry umbilical cameras. On-orbit views of the ET after separation taken by the flight crew revealed a conical shaped feature that may be indicative of residual hydrogen venting from the LH2 ET/ORB umbilical. It appeared to originate from the 4-inch recirculation line interface area. Venting was also visible near the ET intertank and appeared to originate from the GUCP area. The only confirmed anomaly in the intertank area consisted of 10 TPS divots (4 on the -Y side, 6 on the +Y side) in the LH2 tank-to-intertank flange closeout. Loss of TPS from this area has contributed to tile damage on the lower surface of the Orbiter on previous flights. Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were normal.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums exhibited a total of 22 debonds over fasteners. No hardware was missing from the RH frustum or forward skirt that could have caused the damage to RCC panel #10 on the Orbiter right wing leading edge. The HDP #7 Debris Containment System (DCS) plunger was not seated and was obstructed by a frangible nut half. This was the sixth flight utilizing the optimized link. Twenty percent of the HDP #8 EPON shim material was lost prior to water impact. A stud hang-up had occurred on HDP #4 and the stud hole was broached. The HDP #4 EPON shim material was lost at liftoff (as observed in the film review).

A detailed post landing inspection of OV-104 (Atlantis) was conducted on 2-3 April 1992, at KSC and in the OPF (9th landing at KSC). The Orbiter TPS sustained a total of 172 hits, of which 22 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 122 hits, of which 18 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of Orbiter TPS debris hits was greater than average and the number of hits one inch or larger was near average.

An expended NSI detonator with an attached connector coupling ring from the aft umbilical separation system fell to the runway when the RH (LO2) ET umbilical door was opened. A coupler retaining ring from the same detonator was found adhering to some RTV on the inner surface of the RH umbilical door. ET/Orbiter separation ordnance device plungers EO-1 and EO-2 appeared to have functioned properly. However, the EO-3 plunger was obstructed by a detonator booster and frangible nut half. Because of the obstruction of the EO-3 plunger, a detonator booster from the separation assembly escaped and was found in the ET door hinge cavity.

A variety of residuals were present in the Orbiter window samples and indicated sources such as Orbiter TPS, Orbiter window polishing compound, SRB BSM exhaust residue, natural landing site products, organics, and paint. A sample from a tile damage site indicated paint and an iron-rich material of presently unknown origin. This data does not indicate a single source of damaging debris as all of the other materials have been previously documented in post-landing samples. Future revision of this document will include a tabular format of residual results to provide increased sensitivity to possible trends in debris analytical data.

A total of eleven Post Launch Anomalies, including one IFA candidate, were observed during this mission assessment.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

Team Composition: NASA KSC, NASA MSFC, NASA JSC,
LSOC SPC, RI - DOWNEY, MMMSS - MAF,
USBI - BPC, MTI - UTAH

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective: Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.

Areas: MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle external surfaces

Time: L - 1 day

Requirements: OMRSD S00U00.030 - An engineering debris inspection team shall inspect the Shuttle and launch pad to identify and resolve potential debris sources. The prelaunch vehicle and pad configuration shall be documented and photographed.

Documents: OMI S6444

Report: Generate PR's and recommend corrective actions to pad managers.

2) Launch Countdown Firing Room 2

Objective: Evaluate ice/frost accumulation on the Shuttle and/or any observed debris utilizing OTV cameras.

Areas: MLP deck, FSS, Shuttle external surfaces

Time: T - 6 hours to Launch + 1 hour or propellant drain

Requirements: OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization.

Documents: OMI S0007, OMI S6444

Report: OIS call to NTD, Launch Director, and Shuttle managers. Generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective: Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.

Areas: MLP deck, FSS, Shuttle external surfaces

Time: T - 3 hours (during 2 hour BIH)

Requirements: OMRSD S00U00.020 - An engineering debris inspection team shall inspect the Shuttle for ice/frost, TPS, and debris anomalies after cryo propellant loading. Evaluate, document, and photograph all anomalies. During the walkdown, inspect Orbiter aft engine compartment (externally) for water condensation and/or ice formation in or between aft compartment tiles. An IR scan is required during the Shuttle inspection to verify ET surface temperatures. During the walkdown inspect ET TPS areas which cannot be observed by the OTV system.

Documents: OMI S0007, OMI S6444

Report: Briefing to NTD, Launch Director, Shuttle management; generate IPR's.

4) Post Launch Pad Debris Inspection

Objectives: Locate and identify debris that could have damaged the Shuttle during launch

Areas: MLP zero level, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to the perimeter fence, walkdown of the beach from Playalinda to Complex 40, aerial overview of inaccessible areas.

Time: Launch + 1 hours (after pad safing, before washdown)

Requirements: OMRSD S00U00.010 - An engineering debris inspection team shall perform a post launch pad/area inspection to identify any lost flight or ground systems hardware and resultant debris sources. The post launch pad and area configuration shall be documented and photographed.

Documents: OMI S0007, OMI S6444

Report: Initial report to NTD and verbal briefing to Level II at L+8 hours; generate PR's.

5) Launch Data Review

Objective: Detailed review of high speed films video tapes, and photographs from pad cameras, range trackers, aircraft and vehicle onboard cameras to determine possible launch damage to the flight vehicle. Identify debris and debris sources.

Time: Launch + 1 day to Launch + 6 days

Requirements: OMRSD S00U00.011 - An engineering film review and analysis shall be performed on all engineering launch film as soon as possible to identify any debris damage to the Shuttle. Identify flight vehicle or ground system damage that could affect orbiter flight operations or future SSV launches.

Documents: OMI S6444

Report: Daily reports to Level II Mission Management Team starting on L+1 day through landing; generate PR's.

6) SRB Post Flight/Retrieval Inspection

Objective: Evaluate potential SRB debris sources. Data will be correlated with observed Orbiter post landing TPS damage.

Areas: SRB external surfaces (Hangar AF, CCAFS)

Time: Launch + 24 hours (after on-dock, before hydrolasing)

Requirements: OMRSD S00U00.013 - An engineering debris damage inspection team shall perform a post retrieval inspection of the SRB's to identify any damage caused by launch debris. Anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Documents: OMI B8001

Report: Daily reports to Level II Mission Management Team. Preliminary report to SRB Disassembly Evaluation Team. Generate PR's.

7) Orbiter Post Landing Debris Damage Assessment

Objective: Identify and evaluate areas of Orbiter TPS damage due to debris and correlate if possible, source and time of occurrence. Additionally, runways are inspected for debris/sources of debris

Areas: Orbiter TPS surfaces, runways

Time: After vehicle safing on runway, before towing

Requirements: OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected by the Team shall be documented and photographed; the proper management authority shall be notified and corrective actions taken.

Requirements: OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but was not present or was not identified during pre-launch runway inspection. Obtain photographic documentation of any debris, debris sources, or flight hardware that may have been lost on landing.

Requirements: OMRSD S00U00.060 - An engineering debris inspection team shall map, document, and photograph debris-related Orbiter TPS damage and debris sources.

Requirements: OMRSD S00U00.012 - An engineering debris damage inspection team shall perform a post landing inspection of the orbiter vehicle to identify any damage caused by launch debris. Any anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Requirements: OMRSD V09AJ0.095 - An engineering debris inspection team shall perform temperature measurements of RCC nose cap and RCC RH wing leading edge panels 9 and 17.

Documents: OMI S0026, OMI S0027, OMI S0028

Report: Briefing to NASA Convoy Commander and generate PR's. Preliminary report to Level II on the day of landing followed by a more detailed update the next day.

8) Level II report

Objective: Compile and correlate data from all inspections and analyses. Results of the debris assessment, along with recommendations for corrective actions, are presented directly to Level II via SIR and PRCB. Paper copy of complete report follows in 3 to 4 weeks. (Ref NASA Technical Memorandum series).

3.0 PRE-LAUNCH BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 22 March 1992 at 0800 hours with the following key personnel present:

S. Higginbotham	NASA - KSC	STI, Ice/Debris Assessment
B. Davis	NASA - KSC	STI, Ice/Debris Assessment
G. Katnik	NASA - KSC	Lead, Ice/Debris/Photo Team
B. Speece	NASA - KSC	Lead, ET Thermal Protection
B. Bowen	NASA - KSC	ET Processing, Ice/Debris
K. Tenbusch	NASA - KSC	ET Processing, Ice/Debris
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
J. Rivera	NASA - KSC	Lead, ET Structures
M. Bassignani	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
A. Biamonte	NASA - KSC	ET Processing, Ice/Debris
J. Kercksmar	LSOC - SPC	ET Processing
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
J. McClymonds	RI - DNY	Debris Assess, LVL II Integ
J. Stone	RI - DNY	Debris Assess, LVL II Integ
T. Shawa	RI - LSS	Vehicle Integration
D. Denaberg	USBI - LSS	SRB Processing
J. Cook	MTI - LSS	SRM Processing

These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

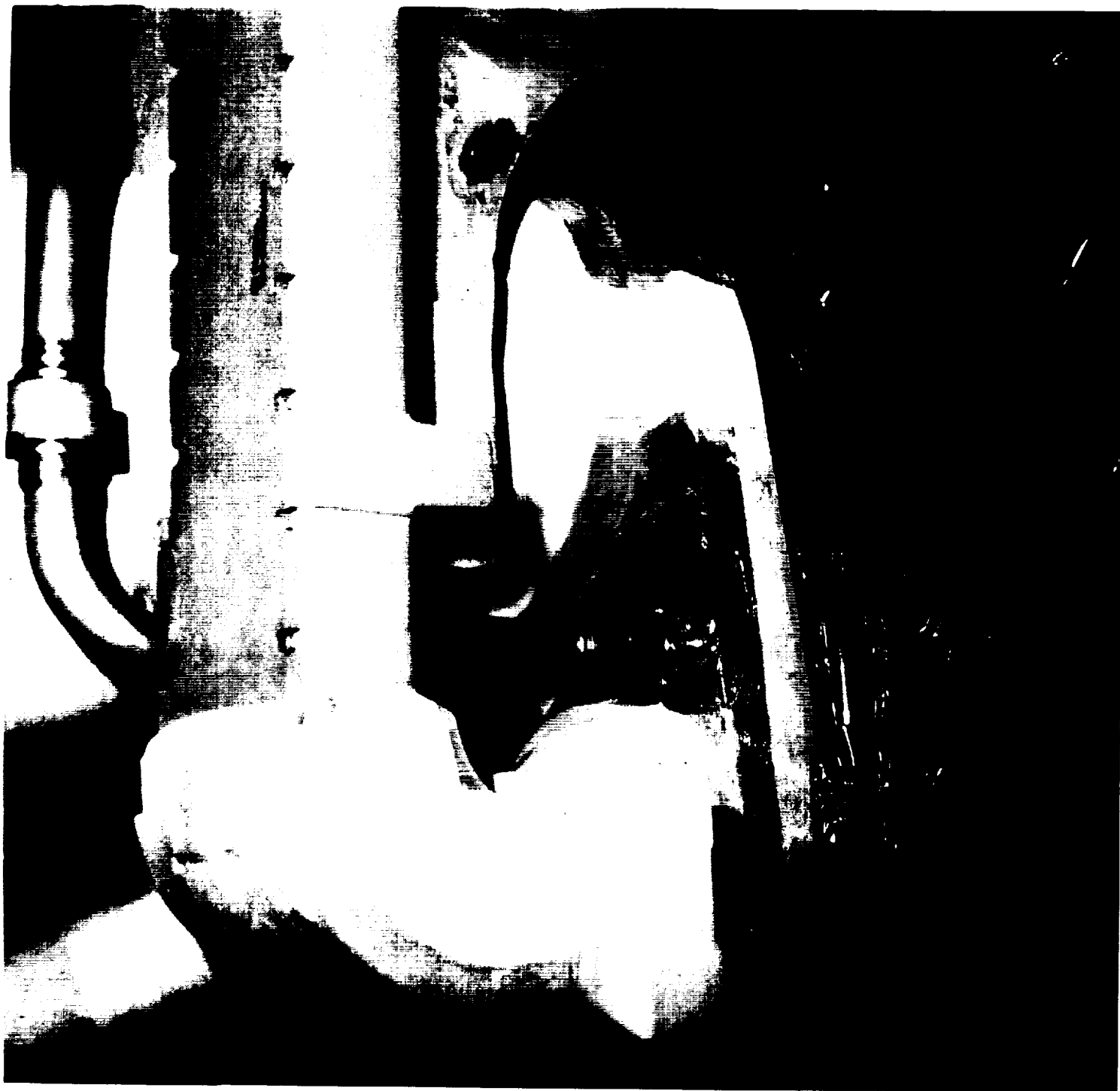
3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 22 March 1992 from 0930 - 1100 hours. The detailed walkdown of Launch Pad 39A and MLP-1 also included the primary flight elements OV-104 Atlantis (11th flight), ET-44 (LWT 37), and BI-049 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor could be designed and installed. The tygon tubes are intended to remain in place during cryogenic loading and be removed by the Ice Team during the T-3 hour hold.

There were no vehicle anomalies.

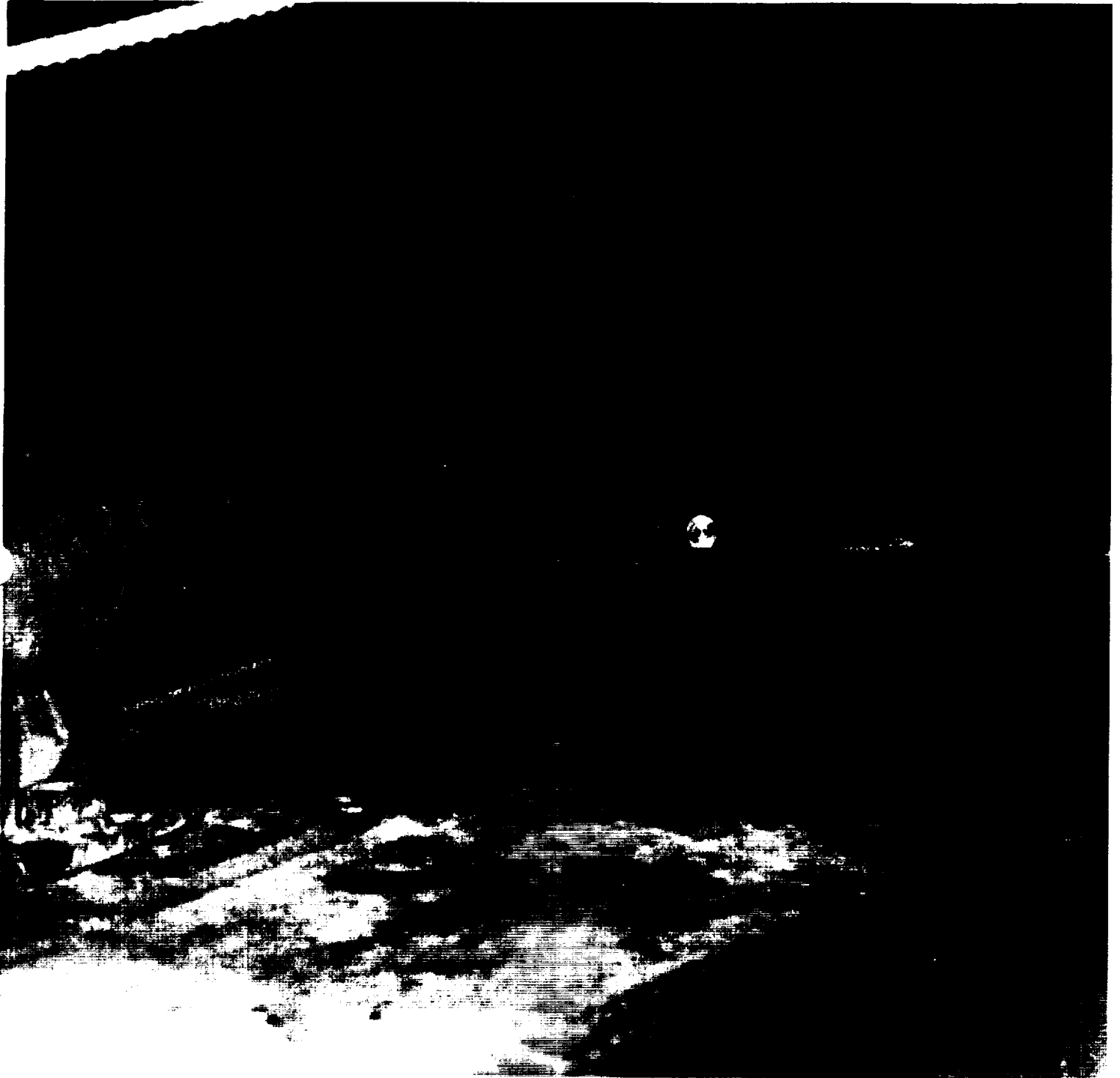
Bolts were loose on a deck plate near the northwest corner of the LH2 TSM, on a deck plate immediately south of the northeast rainbird, and on the LH2 TSM adjacent to the SSME exhaust hole. Loose debris lay on the MLP zero level under the raised decks and in the rain gutters on the east and west sides of the MLP zero level. These discrepancies were corrected real-time by Pad Operations and no items were entered in S0007, Appendix K.



Overall view of the LH2 ET/ORB umbilical outboard side



Configuration of the LH2 ET/ORB umbilical 17-inch flapper valve
torque tool access port TPS plug prior to cryogenic loading



Pneumatic line protective cap under the Firex water pipe

3.2 POST DRAIN INSPECTION

The first launch attempt of STS-45 was scrubbed due to hazardous gas detection system reports of both hydrogen and oxygen leaks (780 ppm and 876 ppm concentrations, respectively) in the Orbiter aft compartment. Data review and isolation troubleshooting did not specifically reveal the source of the leaks. The loading procedure was subsequently changed to remain in slow fill for a longer period to allow for a more gradual thermal transient at the LH2 ET/ORB 17-inch disconnect.

The LH2 tank had been filled to 98 percent; the LO2 tank had been filled to approximately 60 percent. A post drain inspection was performed at Pad 39A from 0900 to 1015 hours on 23 March 1992. Both the SSV and MLP zero level were inspected.

There was no TPS damage, such as divots or cracks, on the LO2 tank, intertank, or LH2 tank acreage.

The tumble valve cover was intact. There was no damage on the -Y side of the nosecone, foot print area, and fairing. The +Y side was not accessible for inspection.

No discrepancies were observed on the bipod jack pad closeouts. Ice was still present in all of the LO2 feedline support brackets, but there was no evidence of loose foam.

Ice still remained in the ET/SRB cable tray-to-upper strut fairing interfaces and on the EB-7/EB-8 fittings.

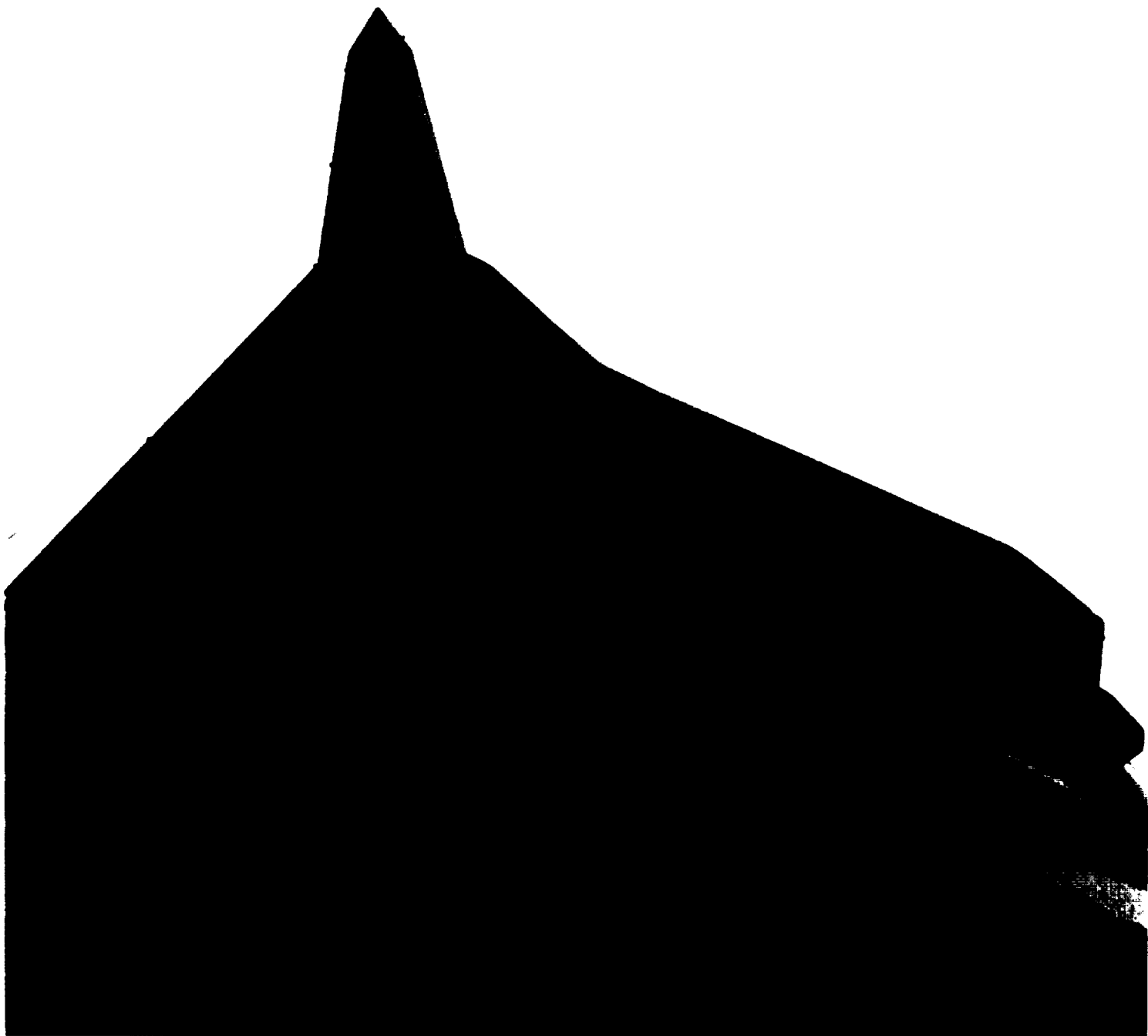
Ice fingers, 3.5 inches in length, were still attached to the LH2 ET/ORB umbilical purge vents. Ice was also present on the aft pyrotechnic canister closeout bondline at the 6 o'clock position and on the 17-inch flapper valve torque tool access port TPS plug closeout at the forward corner.

Frost/vapors were present on the +Z aft siphon manhole cover leak check port closeout.

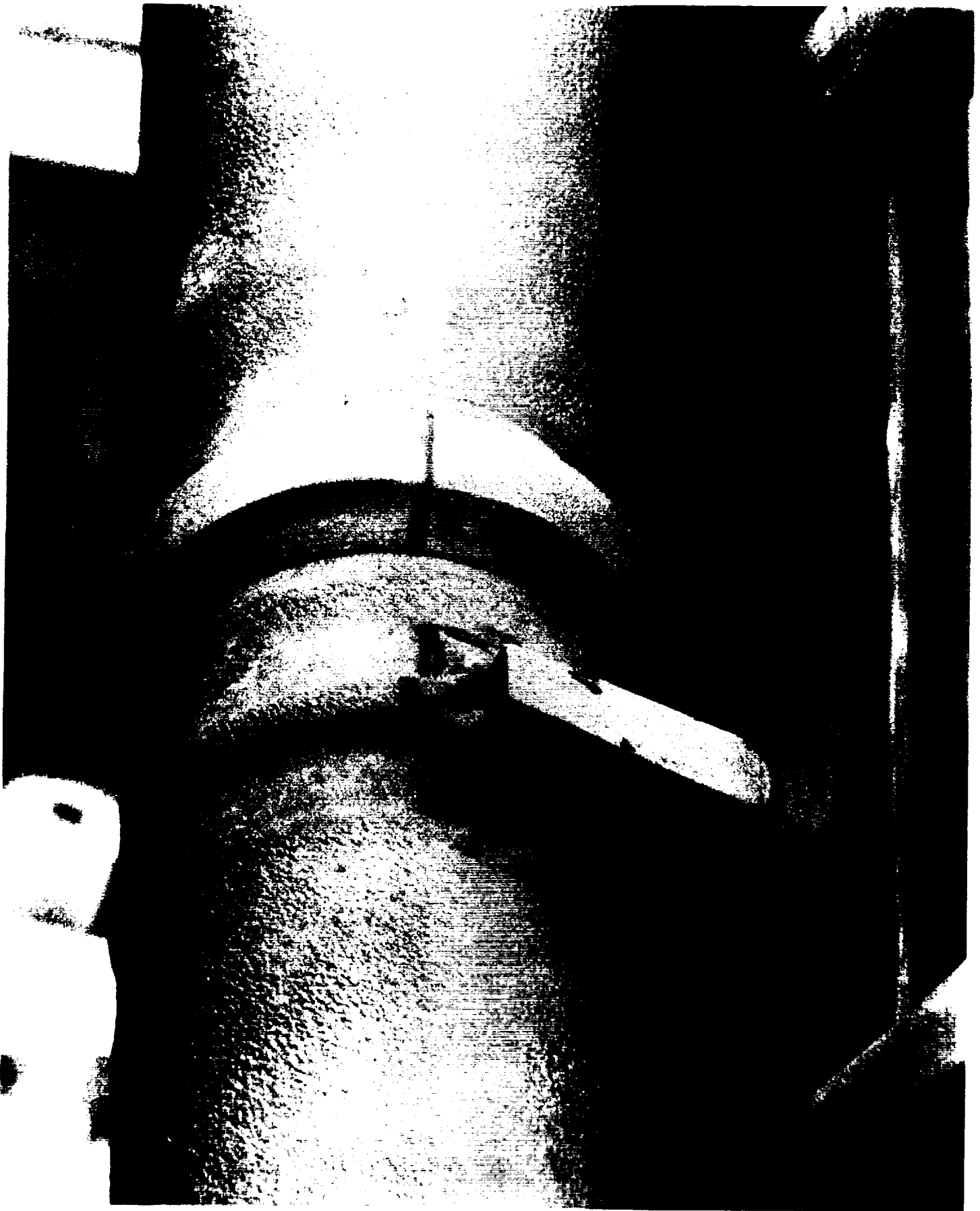
All of the ice/frost conditions were acceptable per NSTS-08303.

There were no apparent TPS anomalies on the SRB's or Orbiter. One RCS paper cover was entirely missing from the R3D thruster on the aft +Y RCS stinger.

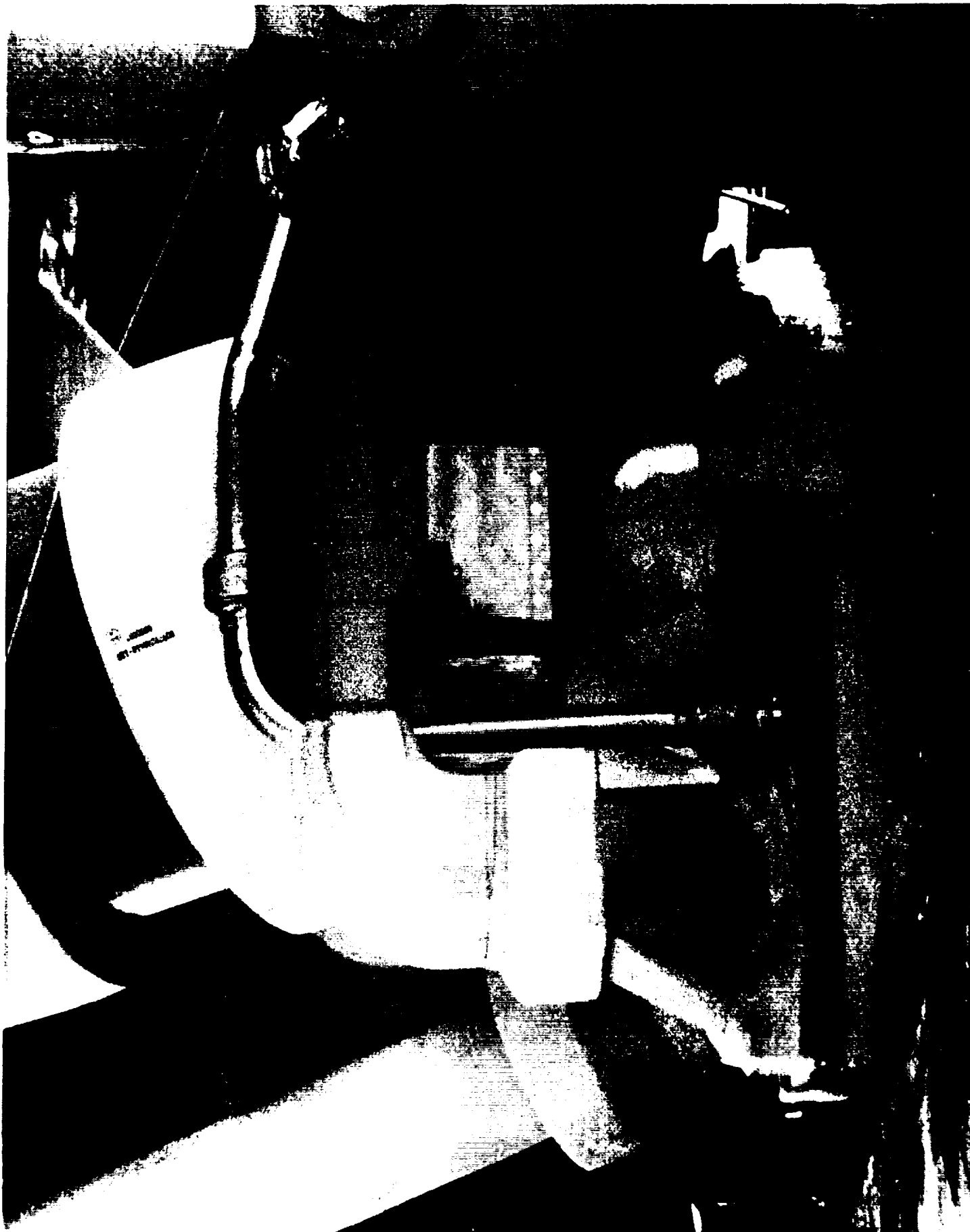
There were no facility anomalies. The sound suppression water troughs were nominally configured and filled with water. The LH2 leak detection tygon tubes for LD54 and LD55 were in the proper positions.



Tumble valve cover was intact. There was no damage on the
-Y side of the nosecone, foot print area, and fairing.



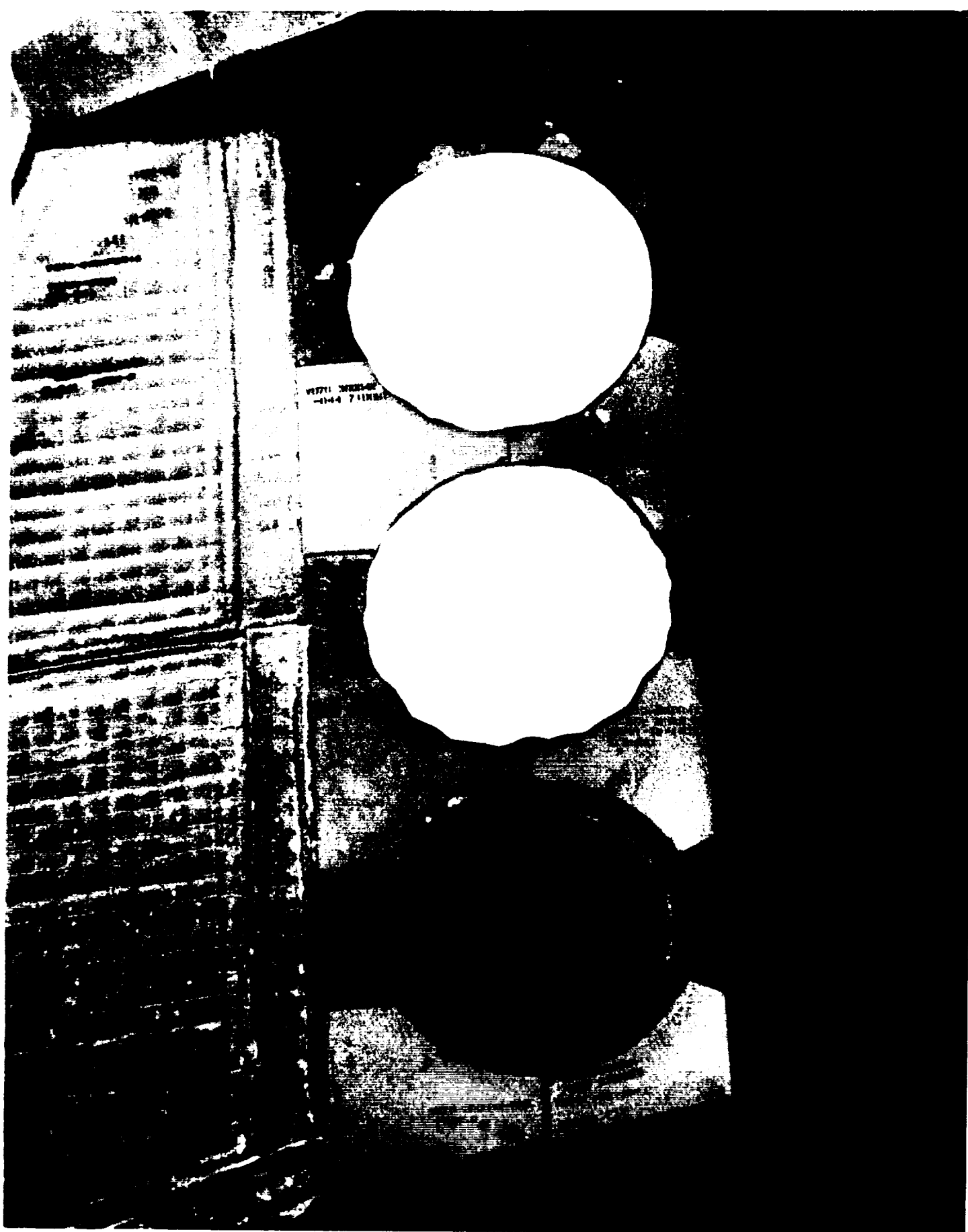
Ice was present in all of the LO2 feedline support brackets,
but there was no evidence of loose foam.



There were no anomalies on the LH2 ET/ORB umbilical. Note the Tygon tube for leak detector LD55 visible above the umbilical (arrow).



Ice was still present on the aft pyrotechnic canister closeout bondline and on the 17-inch flapper valve torque tool access port TPS plug closeout at the forward corner.



One RCS paper cover was entirely missing from the R3D thruster on the aft RH RCS stinger. The condition was waived for flight.

4.0 LAUNCH

STS-45 was launched at 84:13:13:40 GMT (08:13:40 a.m. local) on 24 March 1992.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 24 March 1992 from 0230 to 0435 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no conditions outside of the established data base. Ambient weather conditions at the time of the inspection were:

Temperature:	63.5 F
Relative Humidity:	67.4 %
Wind Speed:	17.9 Knots
Wind Direction:	353 Degrees

The portable Shuttle Thermal Imager (STI) infrared scanner radiometer was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figure 1 and 2.

4.2 ORBITER

No Orbiter tile anomalies were observed. The R3D RCS thruster paper cover was missing. The F1D cover was wet, but intact, with no evidence of a liquid line. The water spray boiler plugs were intact. Light frost was present at the SSME #1 and #2 heat shield-to-nozzle interfaces. The SSME #3 heat shield was dry. Infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No GOX vapors originated from inside the SSME nozzles. No condensate was present on base heat shield tiles.

4.3 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. The K5NA closeouts of the aft booster stiffener ring splice plates were intact. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 59 and 64 degrees F. In comparison, temperatures measured by the hand-held Cyclops radiometer ranged from 60 to 66 degrees F and the GEI (Ground Environment Instrumentation) measured temperatures between 62 and 69 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 65 degrees F, which was within the required range of 44-86 degrees F.

FIGURE 1. SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 0245 - 0430 EST
DATE: 3/24/92
VEH. STS- 45

ALL MEASUREMENTS IN
DEGREES FAHRENHEIT

TARGET EMISSIVITY
ASSUMED TO BE 1.0

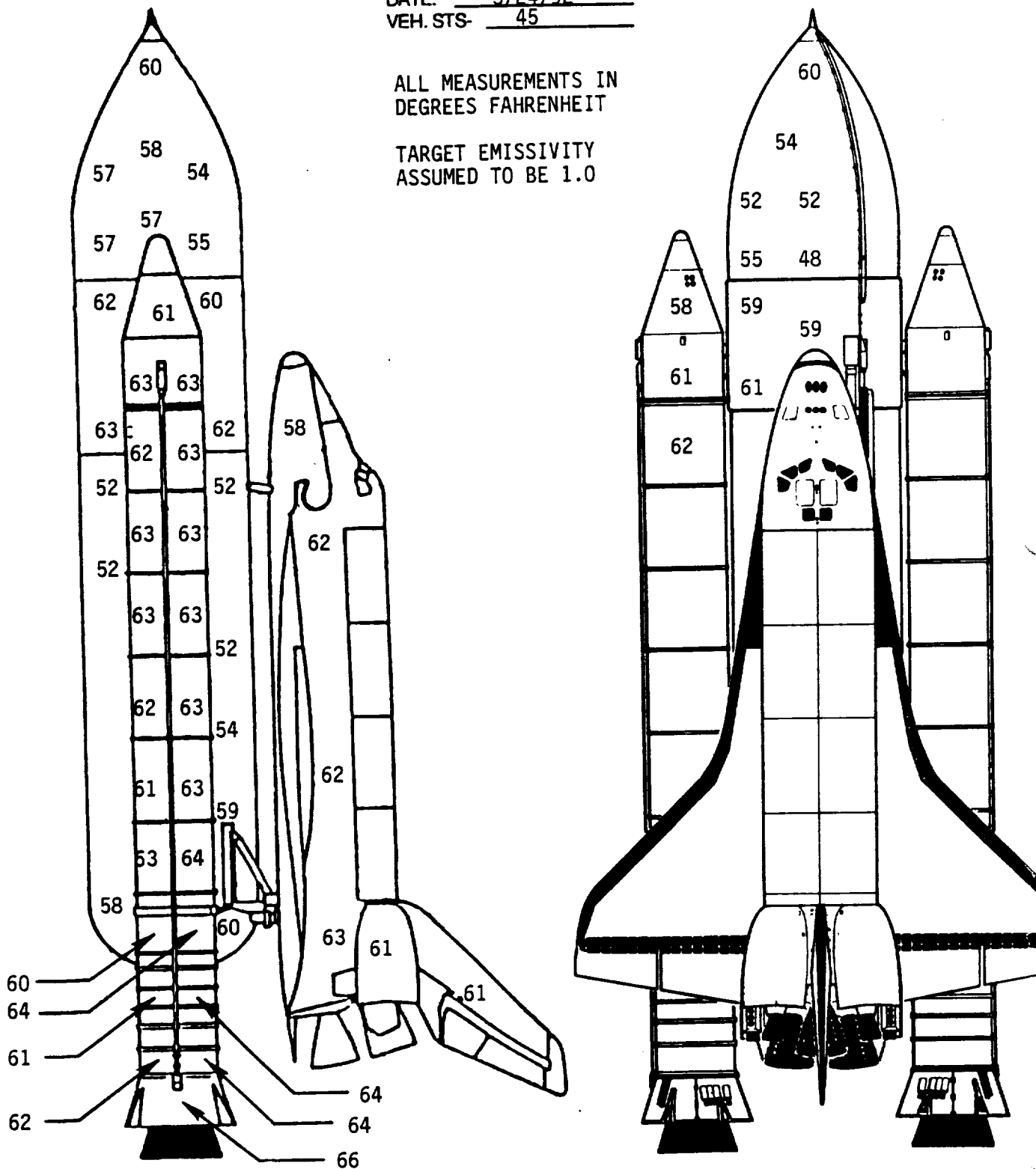
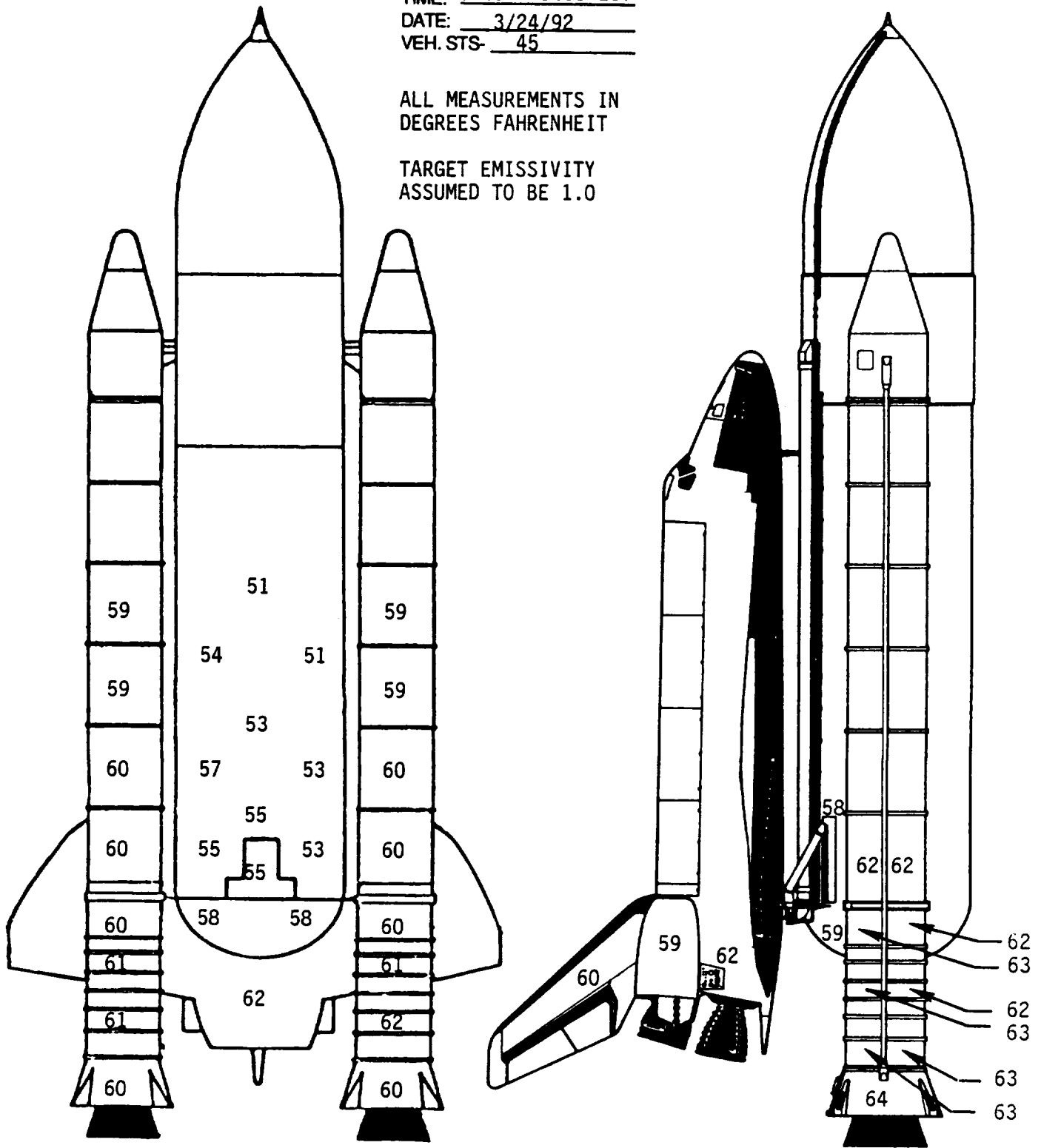


FIGURE 2. **SSV INFRARED SCANNER
SURFACE TEMPERATURE
SUMMARY DATA**

TIME: 0245 - 0430 EST
DATE: 3/24/92
VEH. STS- 45

ALL MEASUREMENTS IN
DEGREES FAHRENHEIT

TARGET EMISSIVITY
ASSUMED TO BE 1.0



4.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 2330 to 0815 hours and the results tabulated in Figure 3. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

There was light condensate but no ice/frost accumulation on the LO2 tank ogive and barrel sections. There were no TPS anomalies. The tumble valve cover was intact. The pressurization line and support ramps were in nominal configuration. The STI measured surface temperatures that averaged 58 degrees F on the ogive and 54 degrees Fahrenheit on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 55 degrees F on the ogive and 55 degrees F on the barrel; SURFICE predicted temperatures of 54 degrees F on the ogive and 50 degrees F on the barrel.

The intertank TPS acreage was dry. No frost spots were present in the stringer valleys. No unusual vapors or ice formations were present on the ET umbilical carrier plate. The portable STI measured surface temperatures that averaged 61 degrees F and the Cyclops radiometer measured temperatures that averaged 62 degrees F.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 52 degrees F on the upper LH2 tank and 56 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 53 degrees F on the upper LH2 tank and 57 degrees F on the lower LH2 tank; SURFICE predicted temperatures of 48 degrees F on the upper LH2 tank and 52 degrees F on the lower LH2 tank.

There were no anomalies on the bipods, bipod jack pad closeouts, PAL ramp, cable tray/press line ice/frost ramps, longerons, thrust struts, manhole covers, or aft dome apex. One small frost spot had formed on the +Y longeron near the thrust strut interface. Some ice/frost was present in the ET/SRB cable tray-to-upper strut fairing expansion joints. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry.

Typical amounts of ice/frost were present in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. There were no accumulations of ice/frost on the acreage areas of the umbilical. Formation of ice/frost on the separation bolt pyrotechnic canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

STS- 45		TEST S0007 LAUNCH				DATE: 24 March 1982		T-0 TIME: 08:13:40		NASA															
ORBITER 104	ET	SRB	MLP	PAD	LO2	CHILLDOWN TIME: 23:58				FAST FILL TIME: 00:17				Ice/Frost/Debris Team											
	44	BI-049	1	A	SLOW FILL TIME: 23:47				REPLENISH TIME: 02:04																
	CONDITIONS					LO2 TANK STA 370 TO 540				LO2 TANK STA 550 TO 852					LO2 TANK STA 1130 TO 1380										
TIME (EST)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	LOCAL VEL KNTS	SOFI TEMP IN/HR	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP IN/HR	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP IN/HR	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP IN/HR	COND RATE IN/HR	ICE RATE IN/HR	
2330	64.40	72.2	55.37	14	357	II	8.26	53.96	0.0008	-0.1724	II	8.26	50.79	0.0025	-0.1432	II	6.16	47.95	0.0030	-0.0966	II	13.86	53.17	0.0020	-0.2459
2345	64.20	73.0	55.48	15	353	II	8.85	54.18	0.0008	-0.1839	II	8.85	51.19	0.0026	-0.1544	II	6.60	48.47	0.0031	-0.1050	II	14.85	53.47	0.0020	-0.2645
0000	64.00	71.0	54.52	18	354	II	10.62	54.17	0.0003	-0.2114	II	10.62	51.58	0.0020	-0.1817	II	7.92	49.19	0.0027	-0.1255	II	17.82	53.59	0.0011	-0.3097
0015	63.80	69.8	53.85	16	353	II	9.44	53.31	0.0004	-0.1841	II	9.44	50.44	0.0021	-0.1549	II	7.04	47.83	0.0027	-0.1051	II	15.84	52.64	0.0012	-0.2661
0030	63.80	70.6	54.17	20	2	I	11.80	54.21	0.0000	-0.2302	II	11.80	51.84	0.0018	-0.2003	II	8.80	49.61	0.0028	-0.1395	II	19.80	53.71	0.0006	-0.3406
0045	64.40	70.2	54.60	15	353	II	8.85	53.77	0.0005	-0.1798	II	8.85	50.77	0.0022	-0.1505	II	6.60	48.06	0.0028	-0.1021	II	14.85	53.04	0.0015	-0.2582
0100	64.40	71.4	55.06	15	356	II	8.85	54.04	0.0007	-0.1824	II	8.85	51.04	0.0024	-0.1530	II	6.60	48.33	0.0029	-0.1040	II	14.85	53.31	0.0017	-0.2622
0115	64.00	71.6	54.75	17	349	II	10.03	54.11	0.0005	-0.2016	II	10.03	51.40	0.0022	-0.1720	II	7.48	48.91	0.0028	-0.1182	II	16.83	53.49	0.0014	-0.2937
0130	63.60	70.2	53.81	18	360	II	10.62	53.60	0.0002	-0.2049	II	10.62	50.99	0.0019	-0.1754	II	7.92	48.59	0.0026	-0.1206	II	17.82	53.01	0.0009	-0.3000
0145	64.00	69.8	54.05	16	359	II	9.44	53.51	0.0004	-0.1862	II	9.44	50.65	0.0021	-0.1589	II	7.04	48.05	0.0027	-0.1067	II	15.84	52.84	0.0012	-0.2691
0200	64.40	68.8	54.05	18	360	I	10.62	54.09	0.0000	-0.2103	II	10.62	51.49	0.0018	-0.1806	II	7.92	49.11	0.0025	-0.1248	II	17.82	53.49	0.0006	-0.3078
0215	64.00	67.4	53.09	16	348	II	9.44	52.98	0.0001	-0.1807	II	9.44	50.11	0.0018	-0.1516	II	7.04	47.51	0.0024	-0.1027	II	15.84	52.29	0.0008	-0.2608
0230	63.80	66.2	52.40	17	349	I	10.03	53.02	0.0000	-0.1866	II	10.03	49.98	0.0015	-0.1574	II	7.48	47.48	0.0022	-0.1070	II	16.83	52.98	0.0003	-0.2708
0245	63.60	66.0	52.13	15	352	II	8.85	52.05	0.0000	-0.1631	II	8.85	48.99	0.0017	-0.1343	II	6.60	46.25	0.0023	-0.0894	II	14.85	51.28	0.0008	-0.2392
0300	63.60	64.4	51.46	18	349	I	10.62	53.19	0.0000	-0.1905	II	10.62	49.68	0.0011	-0.1614	II	7.92	47.28	0.0023	-0.1089	II	17.82	51.96	0.0003	-0.2778
0315	63.20	67.0	52.15	16	348	I	10.62	52.85	0.0000	-0.1926	II	10.62	48.87	0.0015	-0.1694	II	7.92	47.45	0.0022	-0.1113	II	17.82	51.90	0.0003	-0.2813
0330	63.80	67.4	52.90	17	352	I	10.03	53.05	0.0000	-0.1894	II	10.03	50.25	0.0017	-0.1602	II	7.48	47.75	0.0024	-0.1091	II	16.83	52.35	0.0006	-0.2752
0345	63.60	66.8	52.46	18	353	I	10.62	53.24	0.0000	-0.1965	II	10.62	50.23	0.0015	-0.1672	II	7.92	47.82	0.0022	-0.1143	II	17.82	52.25	0.0002	-0.2870
0400	63.60	68.2	53.02	19	3	I	11.21	53.64	0.0000	-0.2106	II	11.21	50.83	0.0015	-0.1811	II	8.96	48.52	0.0023	-0.1248	II	18.81	52.78	0.0003	-0.3086
0415	63.40	70.2	53.62	19	359	II	11.21	53.57	0.0000	-0.2135	II	11.21	51.08	0.0018	-0.1838	II	8.96	48.76	0.0026	-0.1269	II	18.81	53.04	0.0007	-0.3142
0430	63.20	70.4	53.50	20	356	I	11.80	53.62	0.0000	-0.2224	II	11.80	51.18	0.0017	-0.1927	II	8.80	48.94	0.0025	-0.1395	II	19.80	53.07	0.0005	-0.3285
0445	63.40	71.2	54.01	19	359	II	11.21	53.78	0.0002	-0.2161	II	11.21	51.30	0.0020	-0.1864	II	8.36	48.98	0.0027	-0.1288	II	18.81	53.26	0.0009	-0.3181
0500	63.20	69.8	53.27	19	351	I	11.21	53.28	0.0000	-0.2102	II	11.21	50.78	0.0017	-0.1806	II	8.36	48.46	0.0025	-0.1244	II	18.81	52.74	0.0006	-0.3091
0515	63.40	69.4	53.30	19	349	I	11.21	53.45	0.0000	-0.2114	II	11.21	50.90	0.0017	-0.1818	II	8.36	48.58	0.0025	-0.1254	II	18.81	52.85	0.0005	-0.3110
0530	63.20	69.0	52.95	17	350	II	10.03	52.75	0.0001	-0.1870	II	10.03	50.00	0.0018	-0.1577	II	7.48	47.48	0.0025	-0.1071	II	16.83	52.12	0.0009	-0.2717
0545	62.80	70.2	53.03	18	352	II	10.62	52.80	0.0002	-0.1961	II	10.62	50.17	0.0019	-0.1668	II	7.92	47.74	0.0026	-0.1137	II	17.82	52.23	0.0009	-0.2868
0600	62.80	70.0	52.95	18	352	II	10.62	52.76	0.0001	-0.1956	II	10.62	50.13	0.0019	-0.1663	II	7.92	47.70	0.0026	-0.1134	II	17.82	52.18	0.0009	-0.2860
0615	62.60	70.8	53.07	17	1	II	10.03	52.54	0.0004	-0.1848	II	10.03	49.78	0.0021	-0.1557	II	7.48	47.24	0.0027	-0.1053	II	16.83	51.93	0.0012	-0.2687

FIGURE 3. "SURFICE" Computer Predictions

STS- 45		TEST S0007 LAUNCH				DATE: 24 March 1992		T-0 TIME: 08:13:40		NASA KSC				
ORBITER 104	ET 44	SRB BI-049	MLP 1	PAD A	LO2	CHILLDOWN TIME: 23:58		FAST FILL TIME: 00:17		Ice/Frost/Debris Team				
						SLOW FILL TIME: 02:04		SLOW FILL TIME: 02:33						
		CONDITIONS		LO2 TANK STA 370 TO 540		LO2 TANK STA 550 TO 852		LH2 TANK STA 1130 TO 1380		LH2 TANK STA 1380 TO 2058				
TIME (EST)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG KNTS	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0630	62.80	72.0	53.72	16	357	9.44	52.79	0.0008	-0.1789	II	9.44	49.89	0.0023	-0.1497
0645	63.00	73.0	54.30	15	356	8.85	52.97	0.0008	-0.1721	II	8.85	49.93	0.0025	-0.1430
0700	63.40	73.4	54.84	17	359	10.03	53.90	0.0007	-0.1994	II	10.03	51.16	0.0024	-0.1698
0715	63.80	73.8	55.38	16	355	9.44	54.18	0.0008	-0.1932	II	9.44	51.33	0.0026	-0.1636
0730	63.60	73.6	55.11	14	353	8.26	53.45	0.0010	-0.1678	II	8.26	50.25	0.0027	-0.1386
0745	64.40	72.8	55.60	12	358	7.08	53.48	0.0011	-0.1500	II	7.08	49.89	0.0027	-0.1211
0815	66.20	72.0	57.06	14	352	8.26	55.74	0.0008	-0.1892	II	8.26	52.64	0.0026	-0.1595
AVG		63.68	70.04	53.81	16.9	N	10.00	53.47			7.45	48.11		16.77
		52.77												

Period of Ice Team Inspection

FIGURE 3. "SURFACE" Computer Predictions

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Isolated ice/frost formations were present on the outboard and top sides of the LH2 ET/ORB umbilical purge barrier. Ice/frost fingers 3-5 inches in length had formed on the pyro canister and plate gap purge vents. Ice/frost had formed on the aft pyrotechnic canister bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. (The problem exists through end item EI-66. The mold will be changed to add more foam for EI-67 and subs. An EI spec waiver will be issued for STS-45 and subs until existing items are expended). Normal venting of helium purge gas had occurred during tanking, stable replenish, and launch. There were no unusual vapors emanating from the umbilicals nor any evidence of cryogenic drips. A ring of frost had formed on the cable tray vent hole. A 4-inch diameter ice/frost formation with venting (blowing) purge gas was present on the 17-inch flapper valve actuator access port foam plug forward (top) corner. The ice/frost formation was acceptable for launch per NSTS-08303. MPS evaluated the venting/blowing purge gas and deemed the condition acceptable for launch.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle with no flight hardware contact or TPS damage.

The summary of Ice/Frost Team observations/anomalies consisted of 6 OTV recorded items:

Anomaly 001 documented an ice/frost formation on the LH2 tank aft dome +Z manhole cover closeout ring. The ice/frost was adjacent to the apex on the opposite side of the Orbiter. The condition was acceptable per NSTS-08303. Post drain inspection revealed no evidence of a defect.

Anomaly 002 recorded numerous frost formations and small icicles on the north GOX vent duct. The formations decreased in size as the ambient temperature increased. The condition was within the experience data base and was acceptable per the NSTS-08303 criteria.

Anomaly 003 (documentation only) recorded ice/frost formations in the LO2 feedline bellows and support brackets. These ice and frost formations were acceptable per NSTS-08303.

Anomaly 004 (documentation only) recorded ice/frost formations on the LO2 umbilical purge vents and LH2 umbilical purge vents, purge barrier (baggie), LH2 feedline bellows, and recirculation line bellows. The ice/frost formations were acceptable per NSTS-08303.

Anomaly 005 (documentation only) recorded ice/frost formations on the +Y and -Y longeron-to-thrust strut interface. The ice and frost accumulations were acceptable per NSTS-08303.

Anomaly 006, initiated by the Ice Team, documented an ice/frost formation with blowing (venting) purge gas on the forward corner of the LH2 umbilical 17-inch flapper valve torque tool access port TPS plug closeout. The ice/frost formation was acceptable per NSTS-08303. The vapors and blowing purge gas were evaluated by MPS and deemed acceptable for launch.

4.5 FACILITY

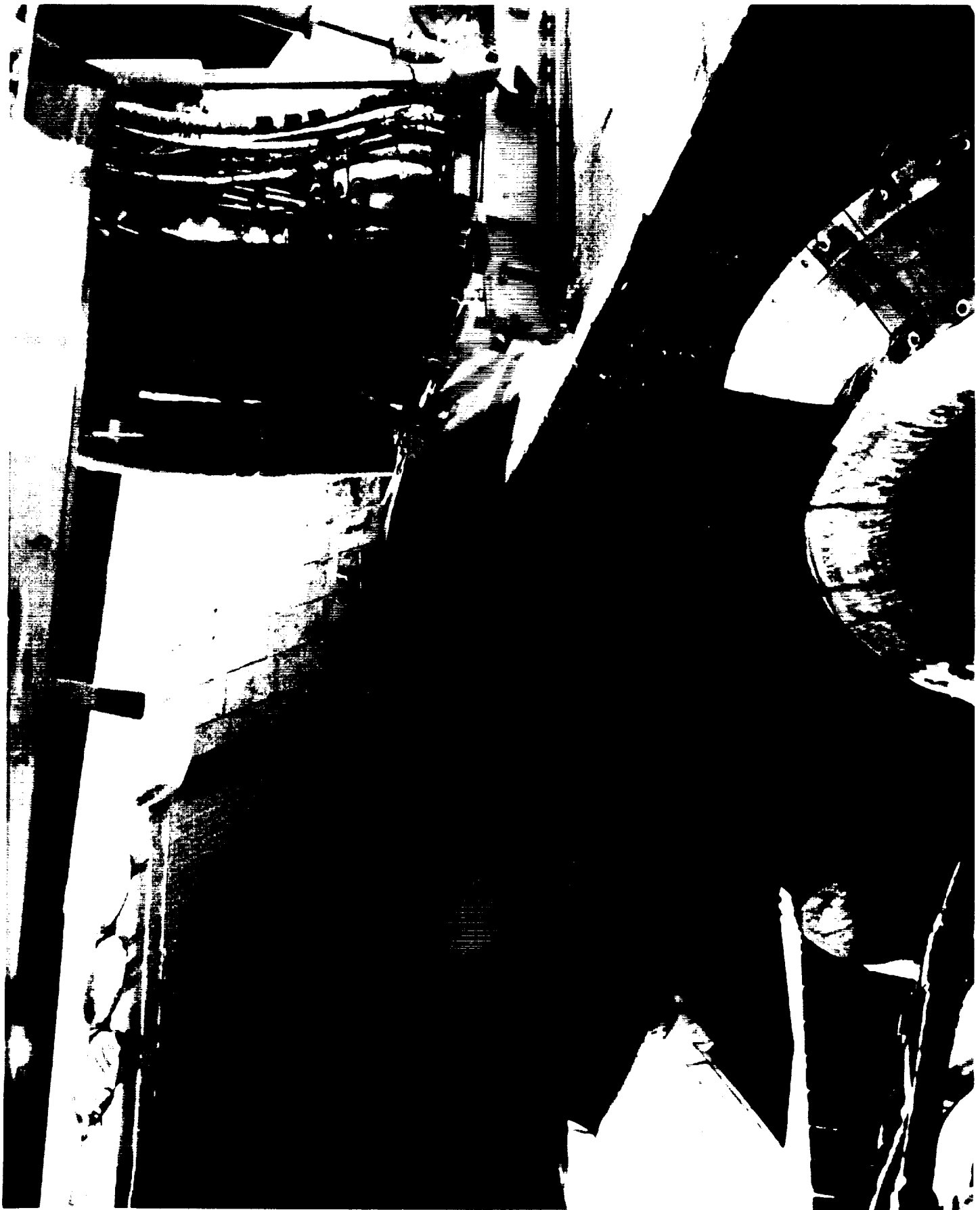
All SRB sound suppression water troughs were filled and properly configured for launch. There was no debris on the MLP deck or in the SRB holddown post areas.

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The GH2 vent line modification prevented ice from forming, but some ice/frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. Small icicles less than 3/4-inch in length had formed on the GOX vent ducts (4 on the south duct, 7 on the north duct) during cryoload, but had melted before launch.



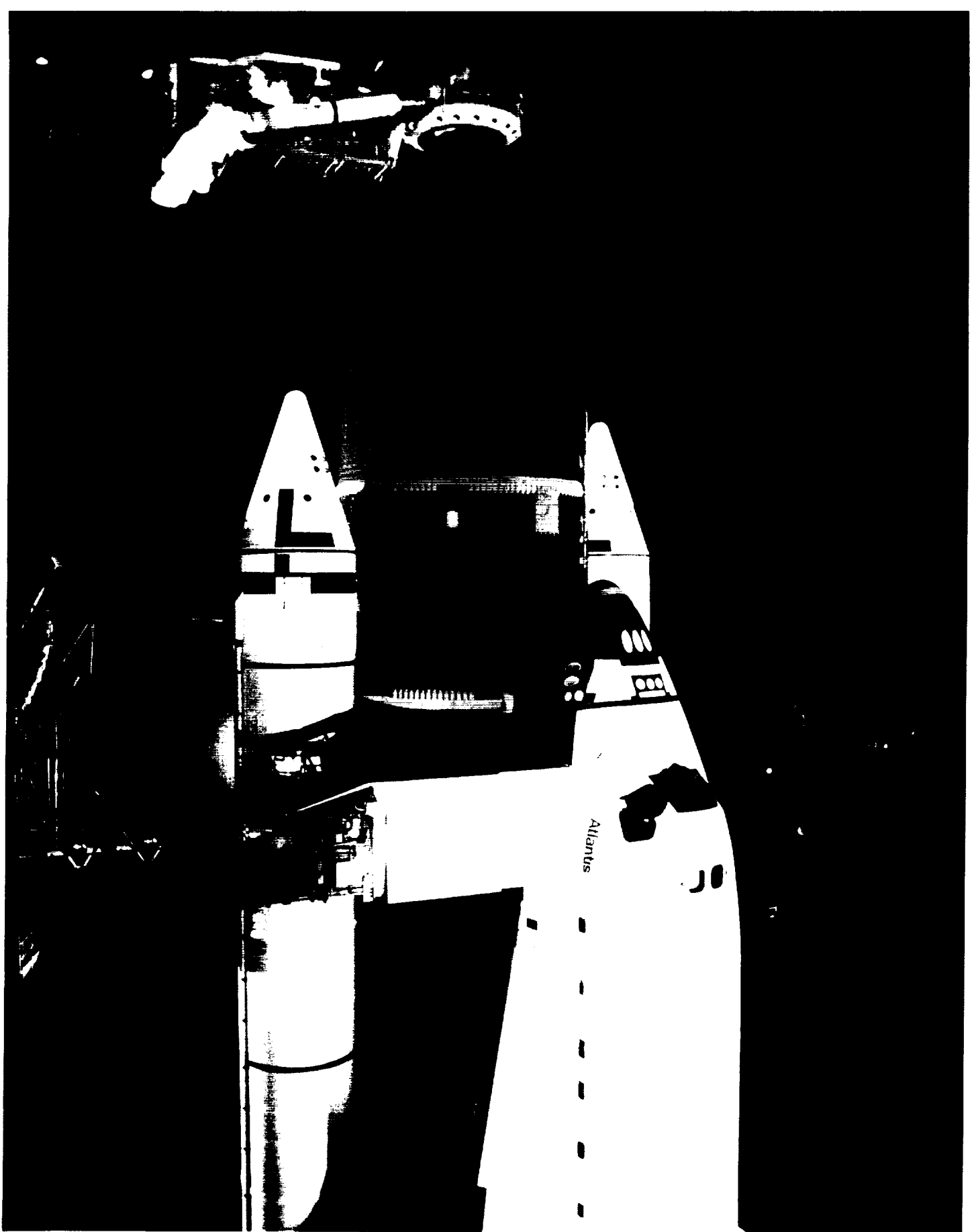
Overall view of OV-104, ET-44 (LWT 37), and BI-049 SRB's. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations



Only the R3D thruster paper cover was missing from the RH aft RCS stinger. The cover fell off after the scrub/ET drain and the condition was waived for launch.



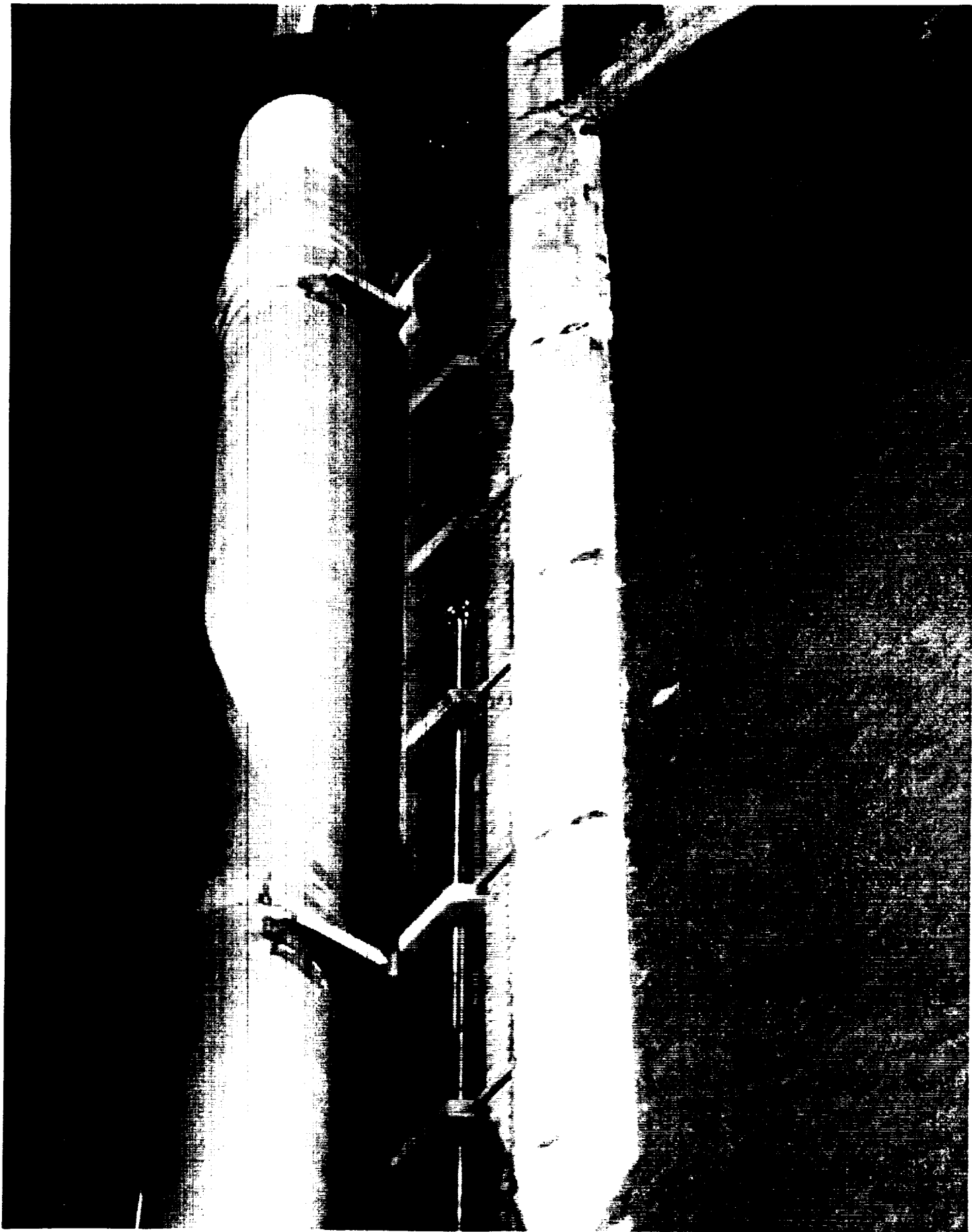
Light frost and condensate was present on the SSME #2 heat shield-to-nozzle interface. No condensate had accumulated on base heat shield tiles.



Light condensate, but no ice or frost, had accumulated on the
ET LO2 tank ogive and barrel sections



There were no LH2 tank TPS anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome.



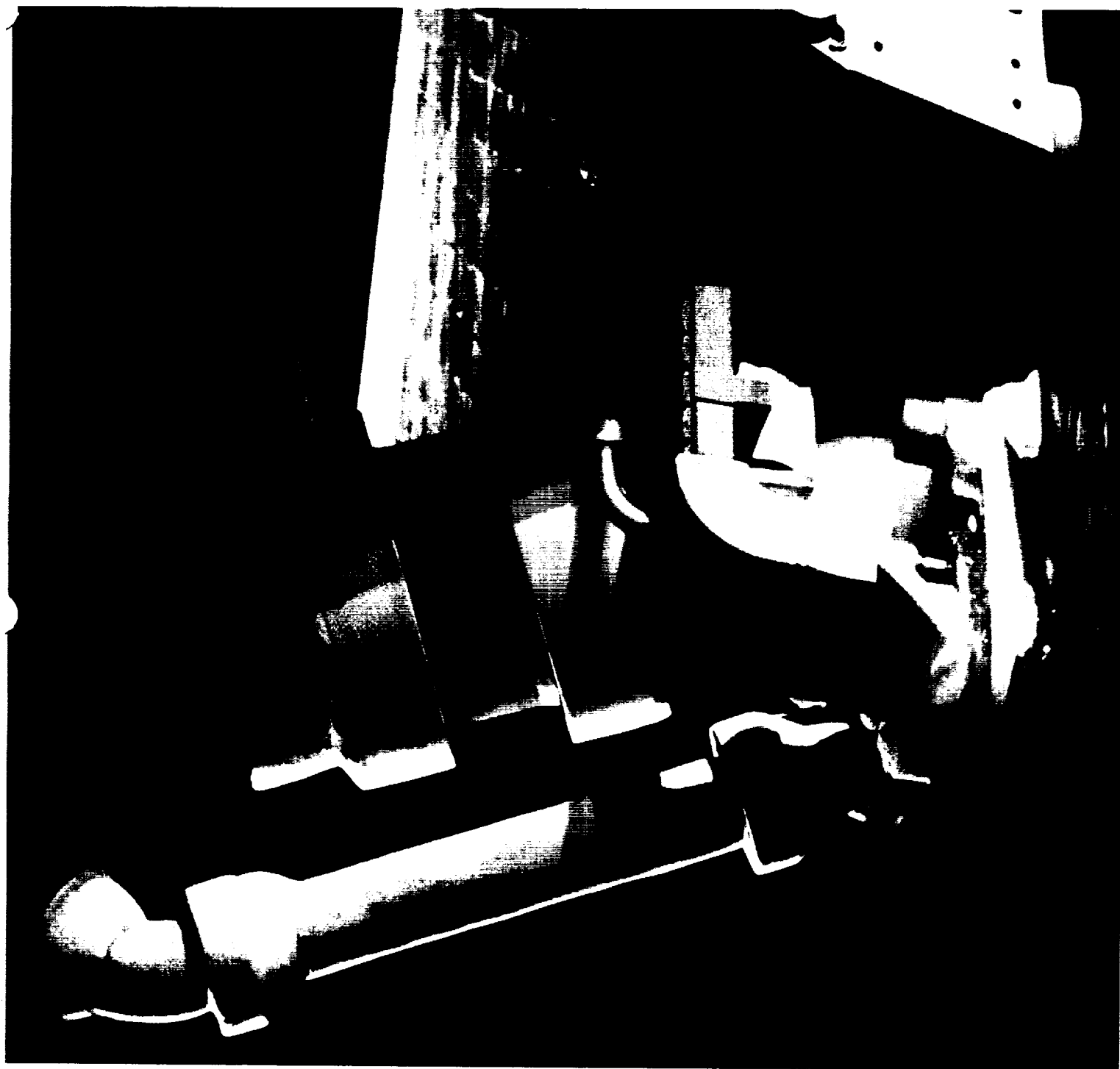
Ice/frost formations in the L02 feedline support brackets and upper bellows were acceptable per the NSTS-08303 criteria.



Ice/frost formations in the L02 feedline support brackets and lower bellows were typical



There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice and frost formations on the purge vents were typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.



Overall view of the LH2 ET/ORB umbilical. There were no unusual vapors emanating from the umbilical nor any evidence of cryogenic drips. Ice/frost accumulations in the recirculation line bellows, on the burst disks, on the umbilical purge vents, and on the top/outboard sides of the umbilical were typical.



Ice/frost formations on the lower plate gap purge vent and in the LH2 recirculation line bellows were typical. The 17-inch flapper valve actuator tool access port TPS plug closeout exhibited a blowing purge gas leak and a 4-inch diameter ice formation at the forward corner. The ice formation was acceptable per NSTS-08303. MPS evaluated the venting/blowing purge gas and deemed the condition acceptable for flight.

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspections of the MLP, FSS, pad apron, and pad acreage were conducted on 24 March 1992 from Launch + 1-1/2 to 4 hours. An 11"x16" piece of white, stitched fabric, insulation material was found in the southwest quadrant of the pad near the box cars/trailers. The material was positively identified as a Dome Mounted Heat Shield (DMHS) thermal protection blanket sacrificial patch. The sacrificial patch was made out of AB-312 ceramic fiber material (ref Attachment 1). No other flight hardware, such as FRSI plugs or tiles pieces, was found.

SRB holddown post erosion was typical. All south HDP EPON shim material was intact, but significantly debonded. The sidewall and bottom plate EPON shim material on HDP #6 was completely debonded. There was no visual indication of a stud hang-up on any of the south holddown posts. The north post doghouse blast covers were in the closed position and three of the covers exhibited minimal erosion. The HDP #3 doghouse blast cover sustained a crack 10 inches long. The SRB aft skirt purge lines were in place but slightly damaged. The RH SRB T-0 umbilical exhibited minor damage. Four electrical connector savers on the LH SRB T-0 umbilical were protruding and damaged.

The GOX vent arm, OAA, and TSM's showed the usual minor amount of damage. The GH2 vent arm was latched on the eighth tooth of the latching mechanism and had no loose cables (static retract lanyard). The GH2 vent line appeared to have retracted normally and showed typical signs of SRB plume impingement. The ET intertank access structure also sustained typical plume heating effects.

Damage to the facility appeared to be less than usual and included:

1. An FSS 155 Foot Level sign was found on the 115 foot level.
2. An FSS 235 Foot Level sign was found on the 215 foot level.
3. Insulation on the north GOX vent duct was torn.
4. An OIS box and an 8"x14" metal panel lay in the south flame trench near the flame diverter. The OIS hardware originated from station 1-17 on the south side of the MLP (near the LH2 skid beneath the overhang). The attach hardware had failed due to corrosion/rusting. The OIS box most likely shook loose from the vibration of launch as the vehicle cleared the tower. Pad Ops will inspect the pad OIS boxes for similar problems.

All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

ATTACHMENT 1

March 26, 1992

TO: Frank Izquierdo

FROM: Heri Soto

SUBJECT: INSULATION FRAGMENT FOUND IN PAD-A AFTER STS-45 LAUNCH

The fragment of insulation found within the Pad-A perimeter after launch of STS-45 can be positively identified as a Dome Mounted Heat Shield (DMHS) thermal protection blanket sacrificial patch. This sacrificial patch is made out of AB-312 material (ceramic fabric) and is intended to protect the weak facing material (S-Glass) of the real 611 DMHS blanket design.

Because the S-Glass fabric material is not strong enough to withstand the fluttering and acoustic loads of flight, the 611 Blankets have been covered with a series of eight sacrificial patches per DMHS half. This sacrificial patch configuration has proven effective in protecting the original 611 blanket from detrimental damage, and it has been approved and accepted as an effective and reliable repair and protection technique by the Material Review Board.

The sacrificial patch consists of a double layer of AB-312 fabric material with a one square-inch grid stitch pattern sewn through the entire patch as structural support. They are sewn to the blanket all around the edges and also with tack stitches through the entire cross-sectional width of the blanket to hold its center to the blankets. See figure 1.

In the past it has been necessary to replace the patches that suffered the greatest damage from flight during orbiter turnaround while at the Orbiter Processing Facility. This damage includes tearing and fraying of the fabric in various degrees, varying from light to extensive damage. Some sacrificial patches have been found to be detached, sometimes from two, up to three edges, but never found to be missing or nearly completely detached from the 611 blanket.

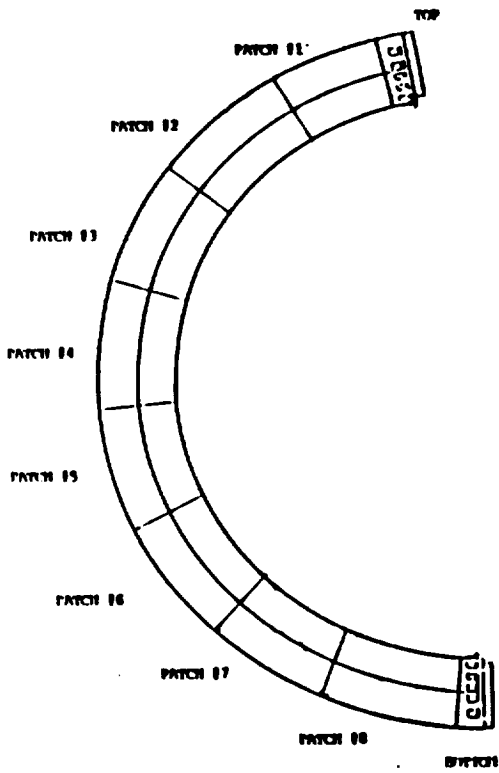
Because all six DMHS blankets (two halves per engine position) are covered and protected entirely with eight sacrificial patches (each), it is impossible at this moment to tell the exact position that the sacrificial patch came from. However, it can be predicted that at the worst case we have the Cerachrome insulating batting material of the blanket missing in this spot since the protective facing material (S-GLASS) is expected to be severely damaged or missing.

We have found missing Cerachrome insulating batting material in the past. However, no thermally induced damage has been recorded on the DMHS structure or nearby SSME powerhead components due to the missing batting material.

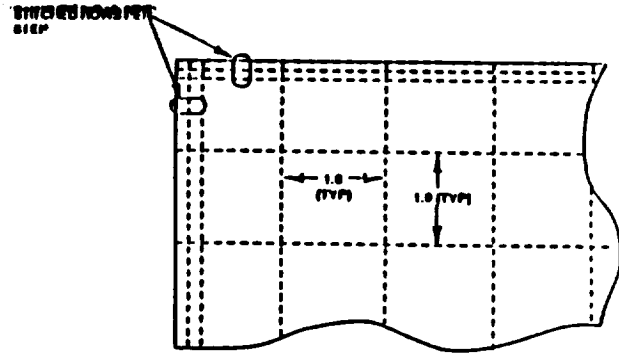
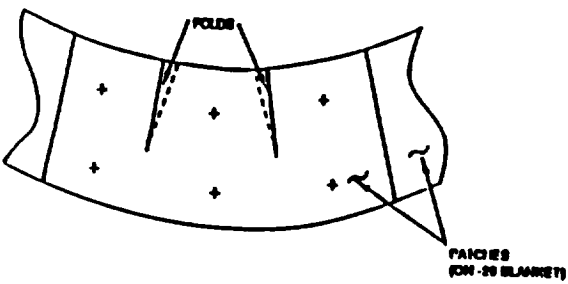

Heri Soto
TV-FSD-11

cc:
HB
DS

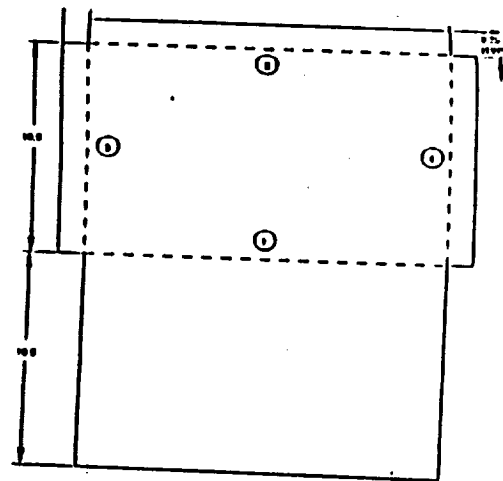
ATTACHMENT 1



DMHS Blanket
showing sacrificial patch position



grid stitch pattern



the making of
a sacrificial patch
(fabric foldlines)

FIGURE 1

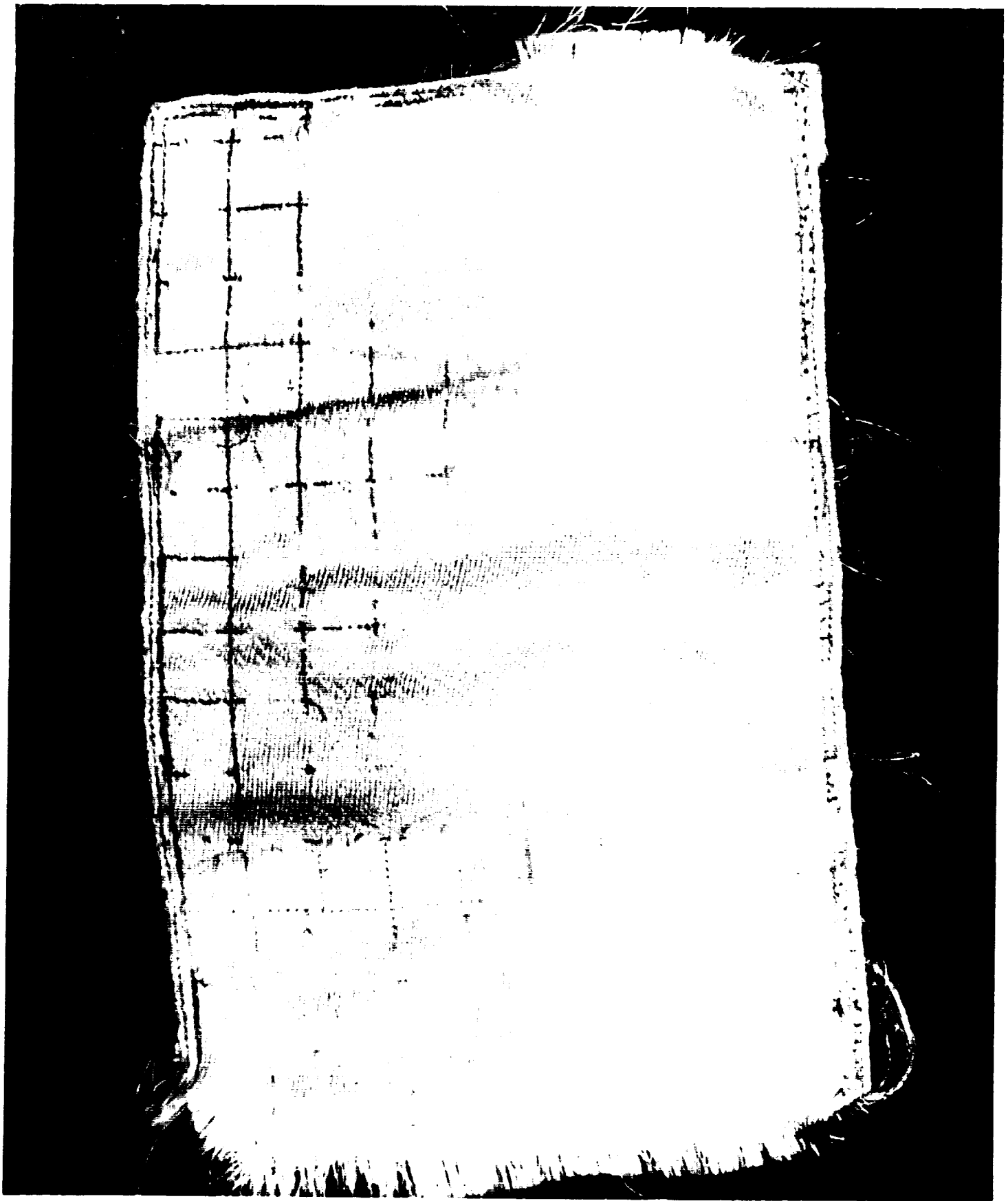
An inspection of the beach from Pad 39B to the Titan complex revealed no flight hardware or TPS materials.

Inspection of the pad was completed on 26 March 1992 along with the areas outside the pad perimeter, railroad tracks, the beach from UCS-10 to the Titan complex, the beach access road, and the ocean areas under the vehicle flight path. A second DMHS thermal protection blanket sacrificial patch (11"x16" in size) was found during the aerial inspection. The material was located southwest of the pad outside the perimeter fence approximately 700 feet from the location of the first piece. Both pieces were in line with the prevailing wind at launch time.

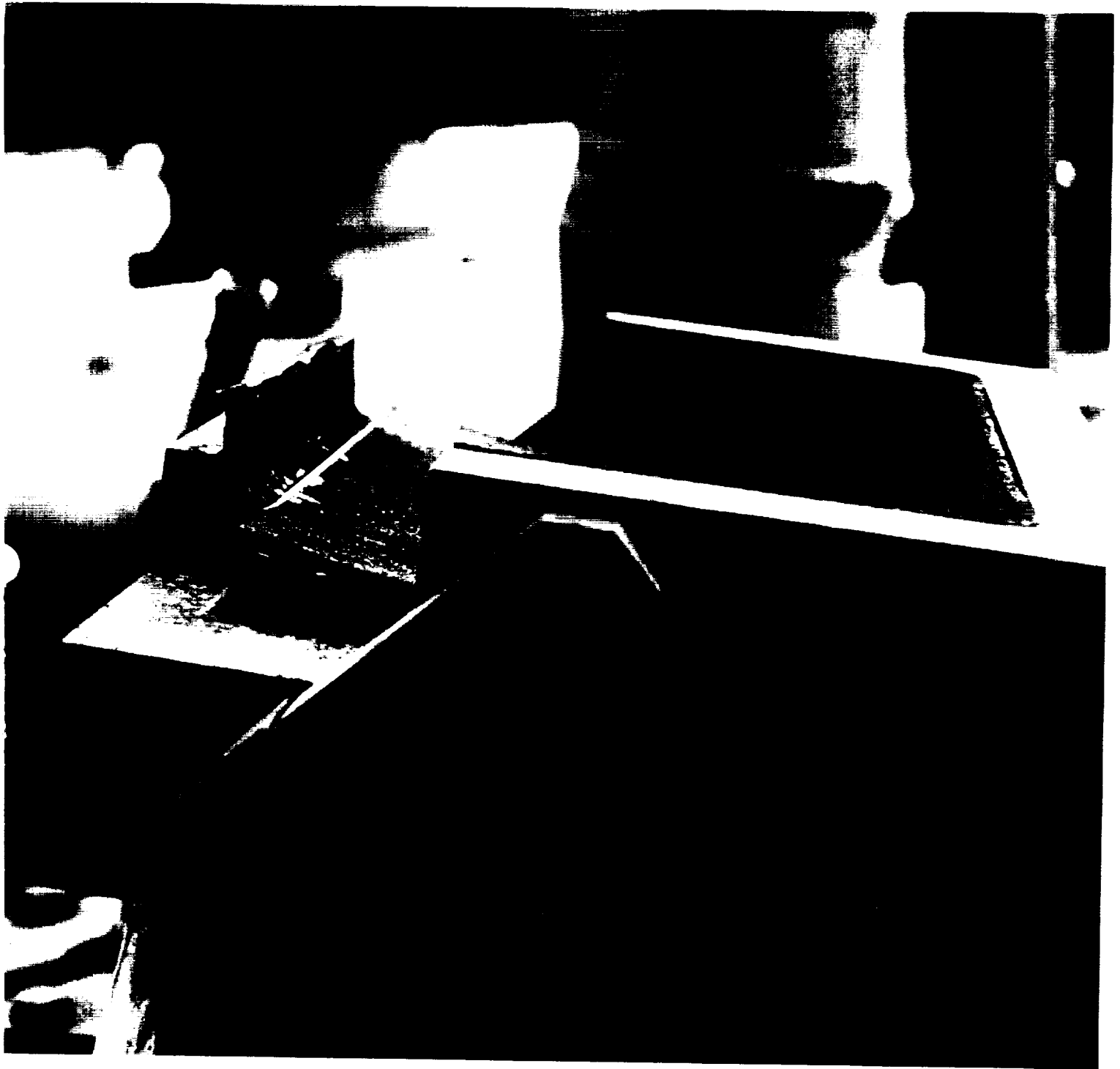
MLP-3 was configured with overpressure sensors at the top of both TSM's, at the bottom of both SRB exhaust holes, and at the bottom of the SSME exhaust hole. All sensor readings were consistent with previous launches and within nominal limits.

Patrick AFB and MILA radars were configured in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent but after SRB separation (due to the masking effect of the SRB exhaust plume). Most of the signal registrations were very weak and often barely detectable, which generally compares with the types of particles detected on previous Shuttle flights. A total of 60 particles were imaged in the T+141.4 to 331.5 second time period. Thirty-one of the particles were imaged by only one radar, 25 particles were imaged by two radars, and four particles were imaged by all three radars.

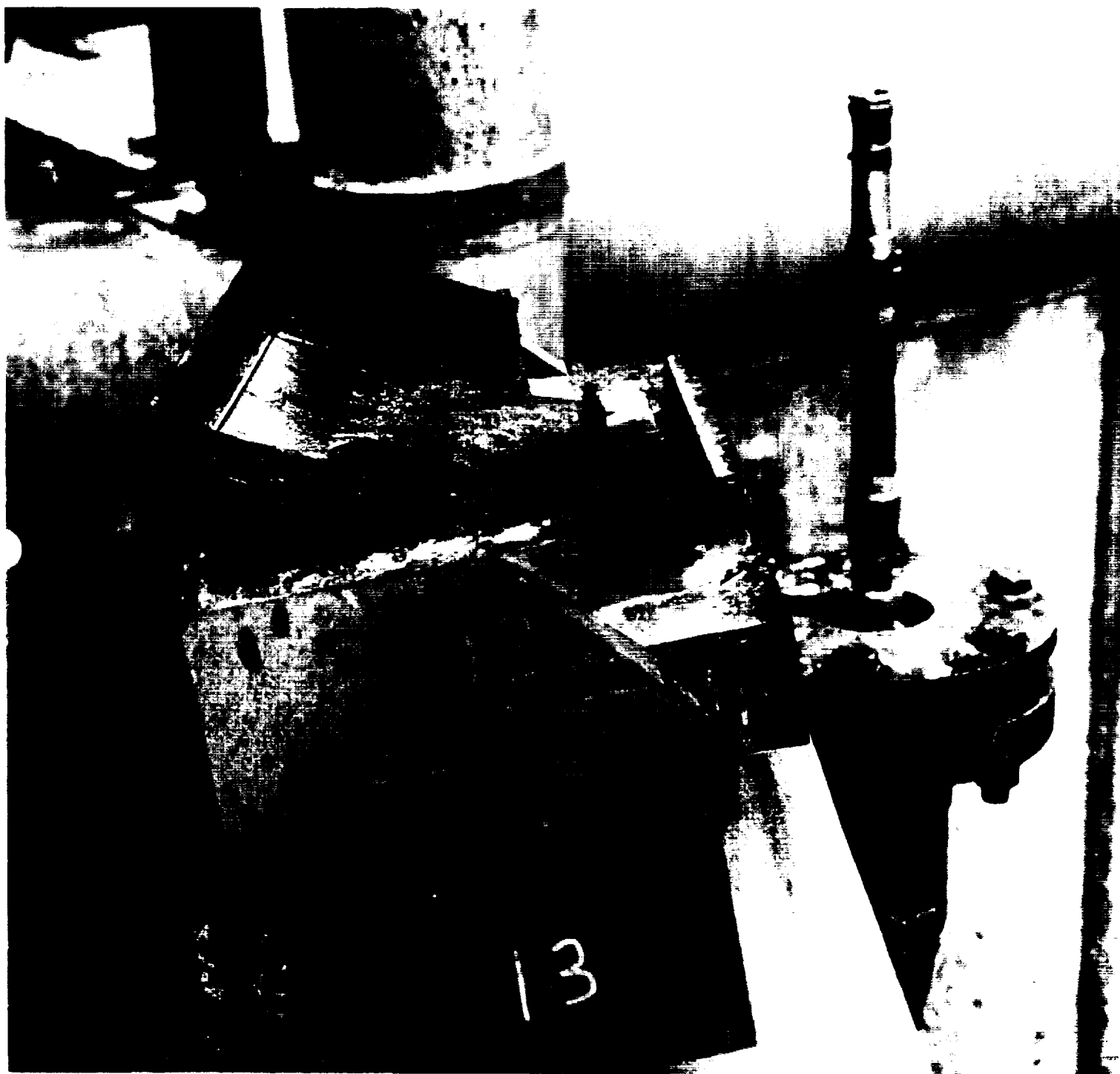
Post launch pad inspection anomalies are listed in Section 10.



Two pieces of SSME Dome Mounted Heat Shield (DMHS) thermal protection blanket sacrificial patches, each measuring 11"x16", were found southwest of the pad apron. Film review showed the patches falling aft of the SSME area at 31 seconds MET.



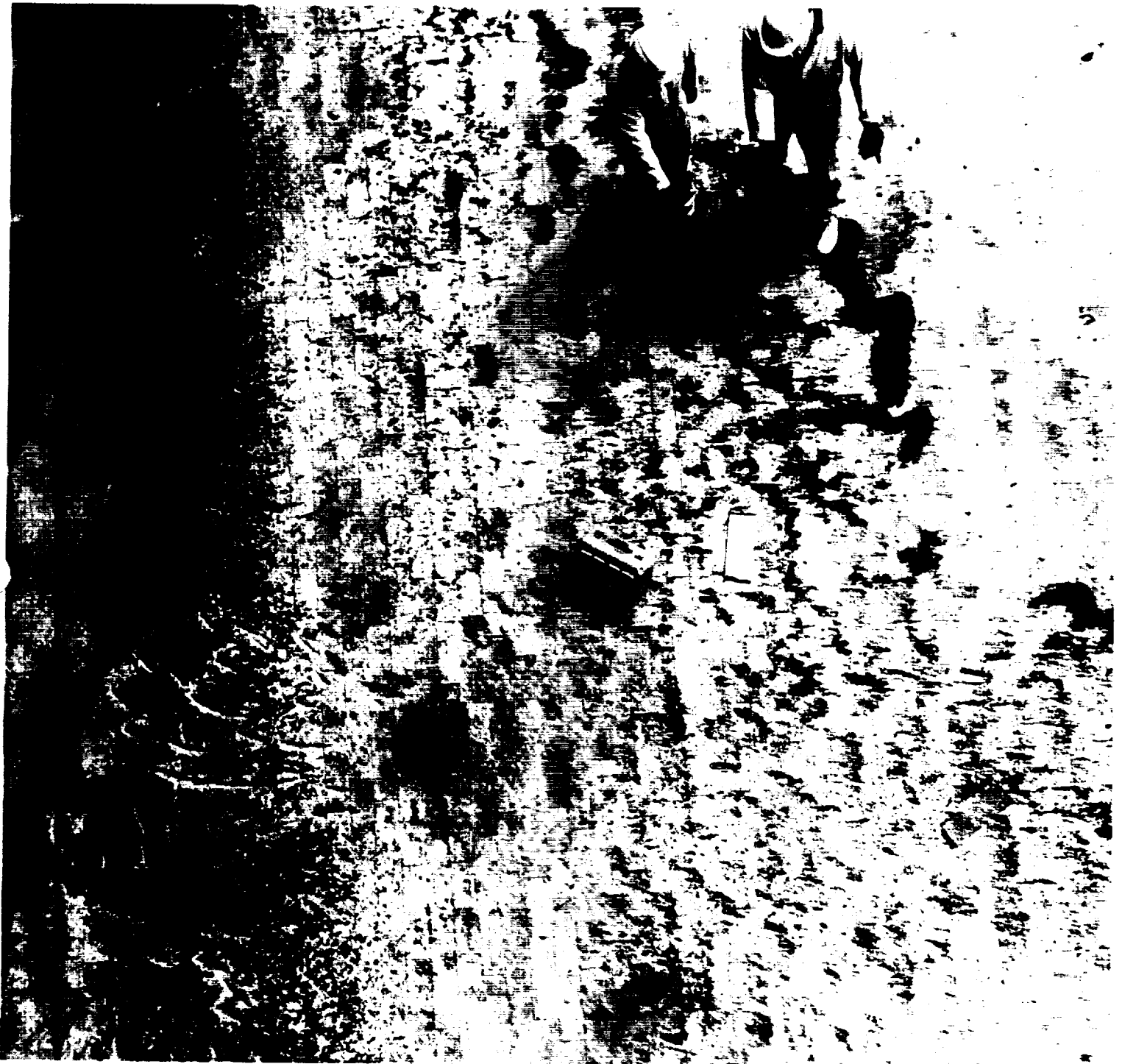
Plume erosion of the south SRB holddown posts was typical. EPON shim material was intact, but significantly debonded. There was no visual indication of a stud hang-up on any of the south holddown posts.



The sidewall and bottom plate EPON shim material on HDP #6
was completely debonded



North HDP blast covers were in the closed position and exhibited typical SRB plume erosion effects



An OIS box and an 8"x14" metal panel lay in the SSME flame trench south of the flame divertor. The OIS hardware originated from the LH2 skid on the south side of the MLP. The attach hardware had failed due to corrosion/rusting.

6.0 FILM REVIEW AND PROBLEM REPORTS

A total of 138 film and video data items, which included fifty-nine videos, fifty-one 16mm films, twenty-four 35mm films, and four 70mm films were reviewed starting on launch day.

Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 10.

6.1 LAUNCH FILM AND VIDEO SUMMARY

No major vehicle damage or lost flight hardware was observed that would have affected the mission.

Helium purge vapors and ice build-up on the LH2 ET/ORB umbilical had been typical during tanking, stable replenish, flight pressurization, and launch. There were no unusual vapors or cryogenic drips (OTV 009, 054, 063).

SSME ignition, Mach diamond formation, and gimbal profile appeared normal. Free burning hydrogen drifted upward to the OMS pods (RSS STI, C/S-2 STI, OTV 051, 063).

SSME ignition caused numerous pieces of ice/frost to fall from the ET/Orbiter umbilicals. No damage to Orbiter tiles or ET TPS was visible (OTV 009, 054, 063, 064). Some pieces of ice contacted the umbilical cavity sill and were deflected outward. No tile damage was visible. Pieces of ice continued to fall from the umbilical area after liftoff.

SSME ignition vibration/acoustics caused the loss of tile surface coating material from three locations on the base heat shield and another location near the LH OMS nozzle heat shield (E-19, 20, E-23).

Several ice particles fell from the LO2 feedline bellows and support brackets, but did not appear to contact the vehicle (E-65).

Light frost was present in the southwest (-Y) ET GOX vent louver. There was no TPS damage to the ET nose cone acreage, footprint, or fairing (OTV 061, 062). ET tip deflection of approximately 32 inches was typical (E-79).

A bright flash near the exit plane of SSME #3 at the time of liftoff was caused by a reflection on the residual GOX cloud from the LO2 T-0 umbilical disconnect, which was drawn aft and around the SSME nozzle by plume aspiration (OTV 051, 070, 071).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 049, 063). A bright flash near the LH2 T-0 umbilical was caused by a reflection of the TSM camera light on the flight QD and residual GH2 vapors (OTV 063). GUCP disconnect from the External Tank was nominal (OTV 004). The GH2 vent arm retracted and latched properly. There was no excessive slack in the static retract lanyard (E-31, 33, 41, 42, 50). Separation of the SRB T-0 umbilicals from the aft skirts was nominal. The separation planes remained generally parallel during retraction (EX2, EX3). Film item E-60 confirmed that water flowed properly from all MLP rainbirds.

A stud hang-up occurred on HDP #4. The EPON shim bottom and sidewall material was pulled loose by the stud (E-7). Two pieces of ordnance/frangible nut debris fell from the HDP #7 DCS/stud hole. A 3"x0.75" debris particle appeared when the vehicle was 18 inches above the HDP shoe (E-28).

The Orbiter RH wing leading edge RCC panel #10 sustained impact damage sometime during the mission. OTV camera 066 performed a surveillance scan of the vehicle at T-1 hr 42 min and confirmed the absence of impact damage. Launch films and high speed photography showed no impacts to this area by debris, such as the OIS box found in the SSME flame trench, during liftoff. Analysis of launch still photographs and original negatives did not reveal any signs of the impacts at the time of launch. No photography was available to establish the RCC panel impact damage occurred during ascent, in orbit, or during re-entry.

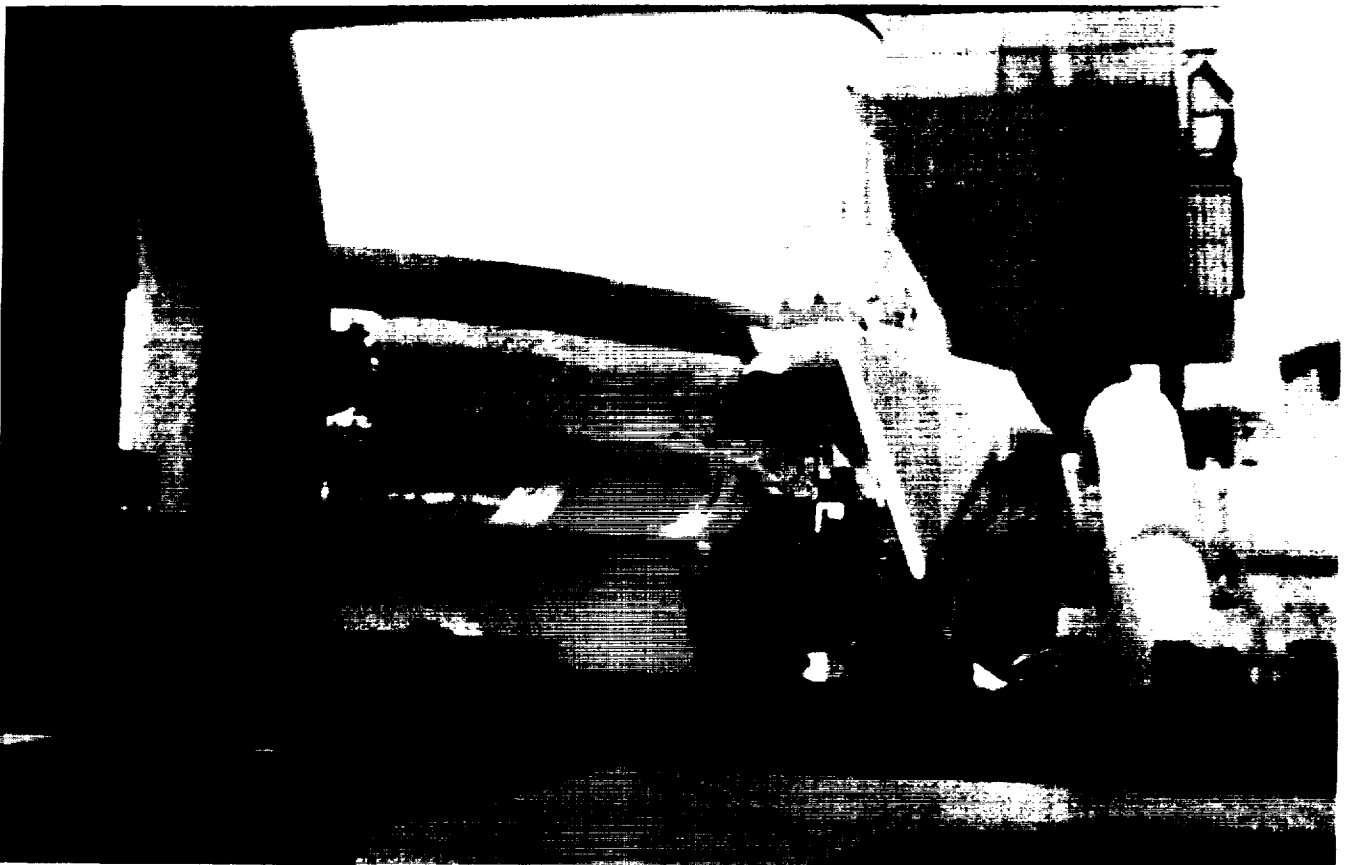
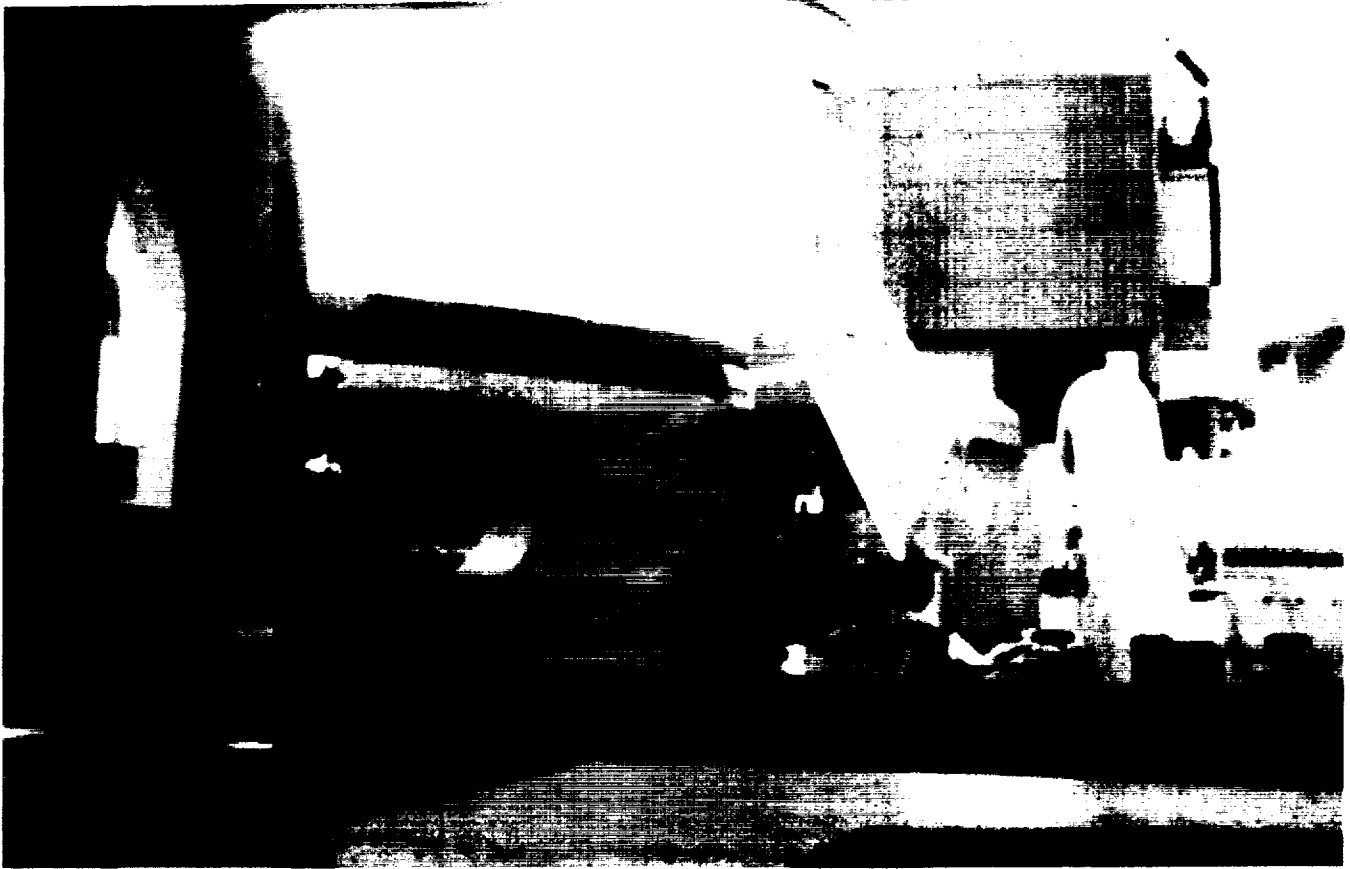
Clusters of particles falling aft of the Orbiter after completion of the roll maneuver were traced to the forward RCS thrusters and were pieces of RCS paper covers. Other pieces of RCS paper covers were visible passing over the Orbiter wings. Pieces of ET/ORB purge barrier baggie material were also visible caught in the aerodynamic recirculation and falling aft of the vehicle (E-54, 59, 212, 213, 223). A white object fell out of the SRB plume at GMT 13:14:27.497 (E-222).

A section of SSME closeout blanket patch material originated near the 9:00 position on SSME #3 and fell aft near SSME #1 at 13:14:11.286 GMT (E-59, ET-212, ET-213, TV-4A). It separated into two pieces (E-212 frame 2050, E-213, E-222) in the SSME plume. This material is most likely the two pieces of SSME closeout blanket patch material found near the pad after launch.

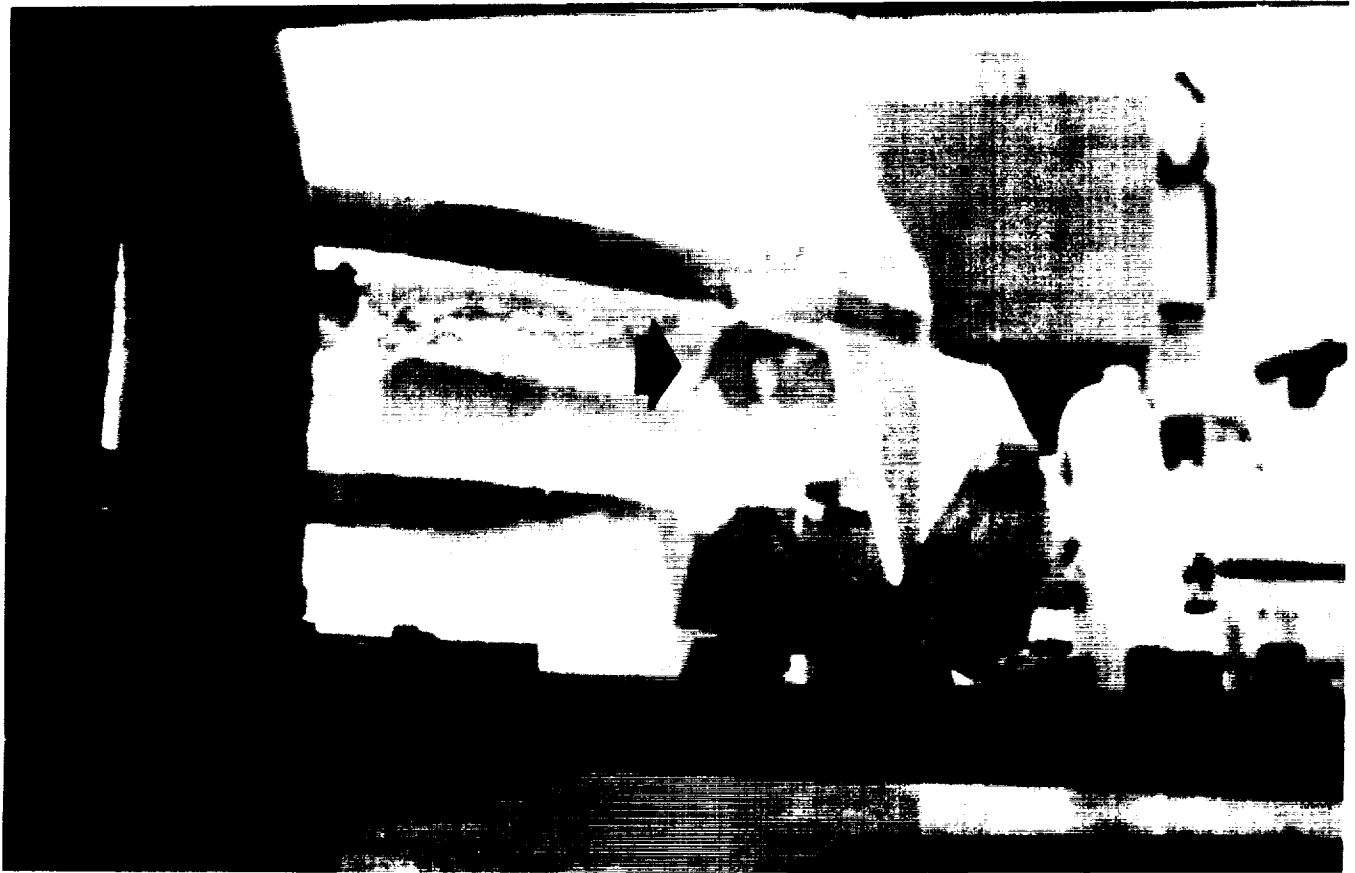
An orange flash occurred in the SSME plume during ascent at GMT 13:14:18.334 (E-54, 222).

Movement of the body flap appeared similar in amplitude and frequency to that observed on previous flights (E-207, 212).

ET aft dome outgassing and charring was typical. Three instances of plume brightening, which have been observed on previous flights, occurred during tailoff. SRB separation appeared normal (OTV 048, TV-13, E-204, 205, 206, 207, 208, 223).



A stud hang-up occurred on HDP #4. The vehicle "walked" to the north and caused the stud to remain extended until clear of the aft skirt, at which point it "twanged" from side to side and eventually fell into the holddown post.



The EPON shim bottom and sidewall material was pulled loose by the stud. The shim pieces fell into the SRB exhaust hole without contacting the vehicle.



Two pieces of ordnance/frangible nut debris fell from the
HDP #7 DCS/stud hole (arrows)



A 3.0"x 0.75" NSI booster fell from the HDP #7 DCS/stud hole
when the vehicle was 18 inches above the HDP shoe



Two pieces of SSME Dome Mounted Heat Shield (DMHS) sacrificial patches originated from SSME #3 and fell aft at 31 seconds MET

6.2 ON-ORBIT FILM AND VIDEO SUMMARY

Views of the External Tank after separation from the Orbiter consisted of one 16mm film and 38 still 70mm frames. OV-104 was not equipped to carry umbilical cameras.

No major vehicle damage or lost flight hardware was observed that would have been a safety of flight concern.

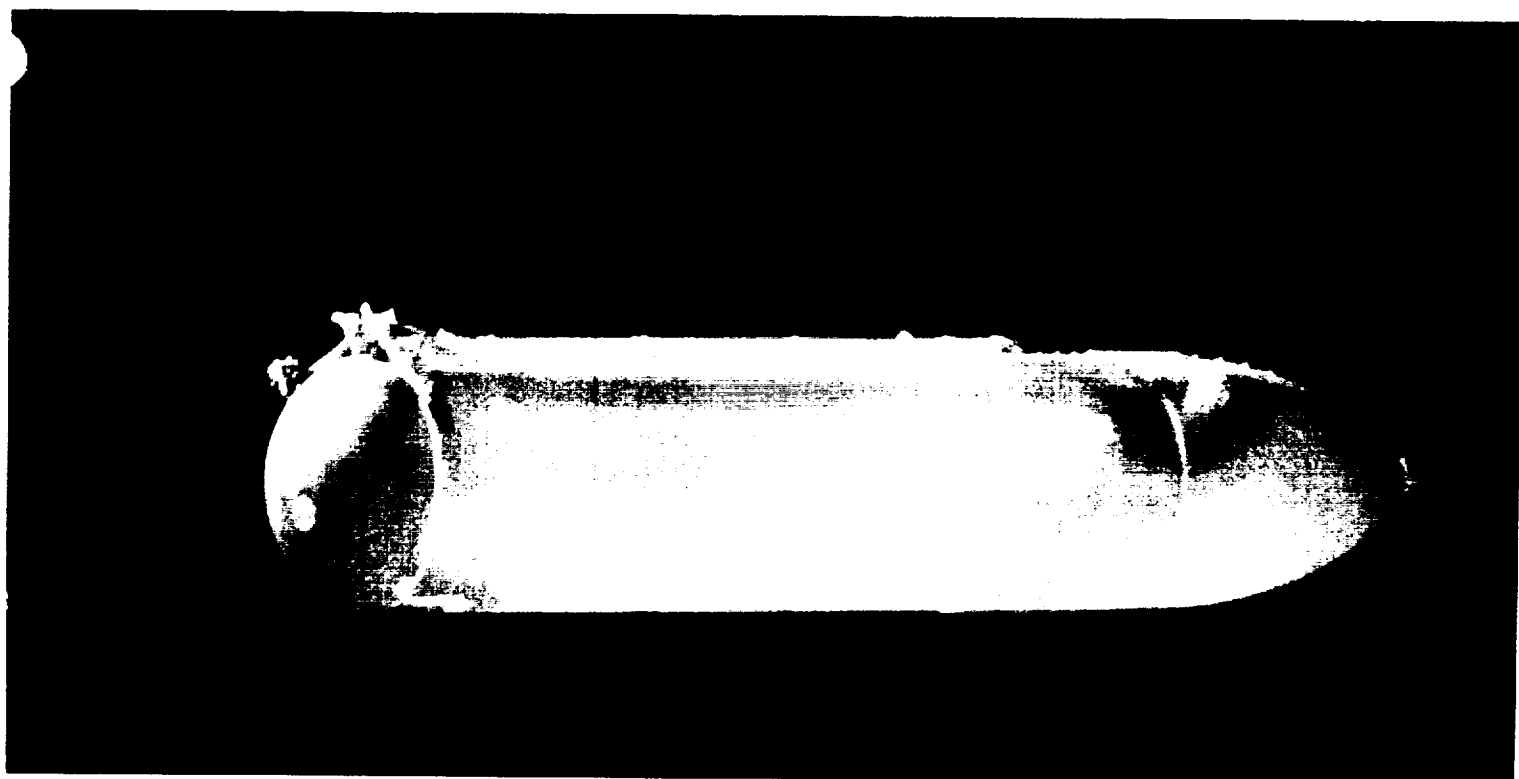
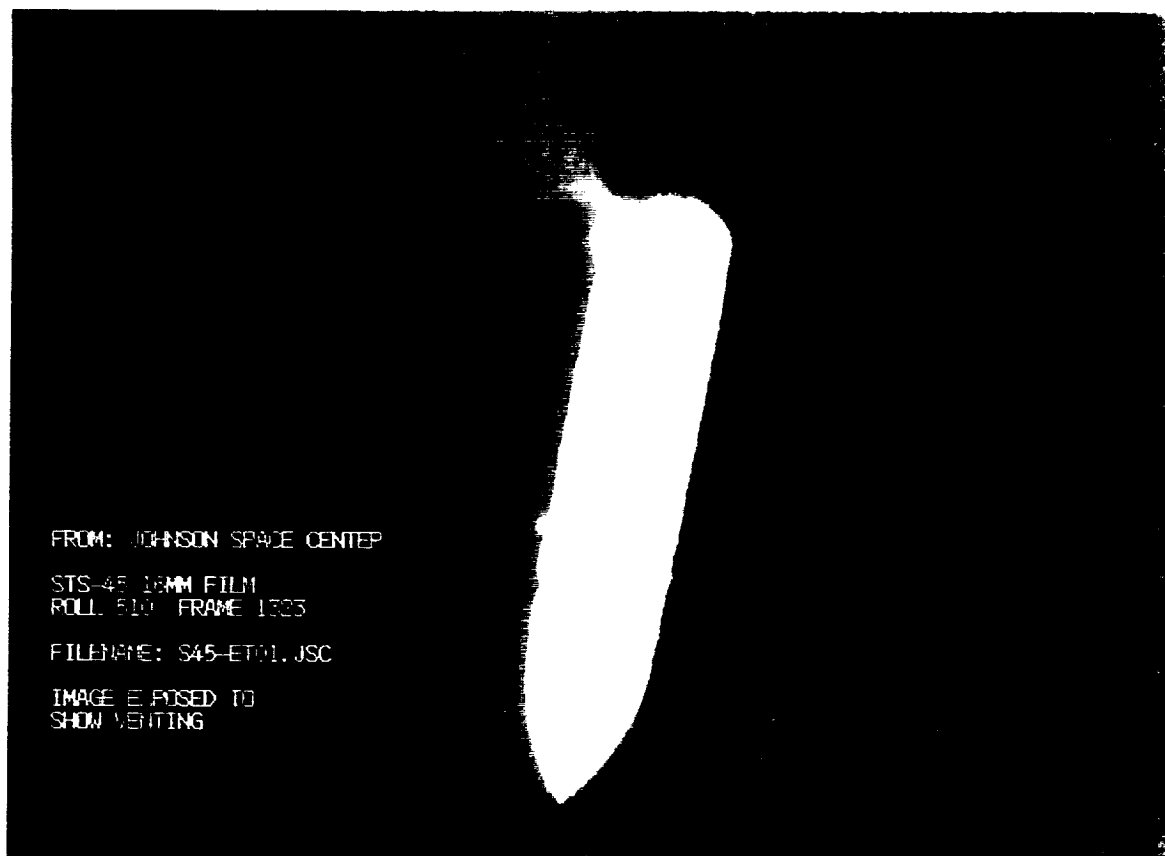
A conical shaped feature that may be indicative of residual hydrogen venting from the LH2 ET/ORB umbilical appeared to originate from the 4-inch recirculation line interface area. Venting was also visible near the ET intertank and appeared to originate from the flight umbilical carrier plate area. The only confirmed anomaly in the intertank area consisted of 10 TPS divots (4 on the -Y side, 6 on the +Y side) in the LH2 tank-to-intertank flange closeout. Loss of TPS from this area has contributed to tile damage on the lower surface of the Orbiter on previous flights.

There were no apparent anomalies on the LO2 tank, LH2 tank, and aft dome TPS acreage. A possible divot was visible on the aft dome between the two manhole covers. The BSM burn scars were typical. The nosecone, intertank access door, GH2 umbilical carrier plate, ET/SRB forward attach points, and RSS antennae were in nominal configuration.

There were no apparent anomalies that may have contributed to the impact damage on the Orbiter right wing leading edge RCC panel #10.

6.3 LANDING FILM AND VIDEO SUMMARY

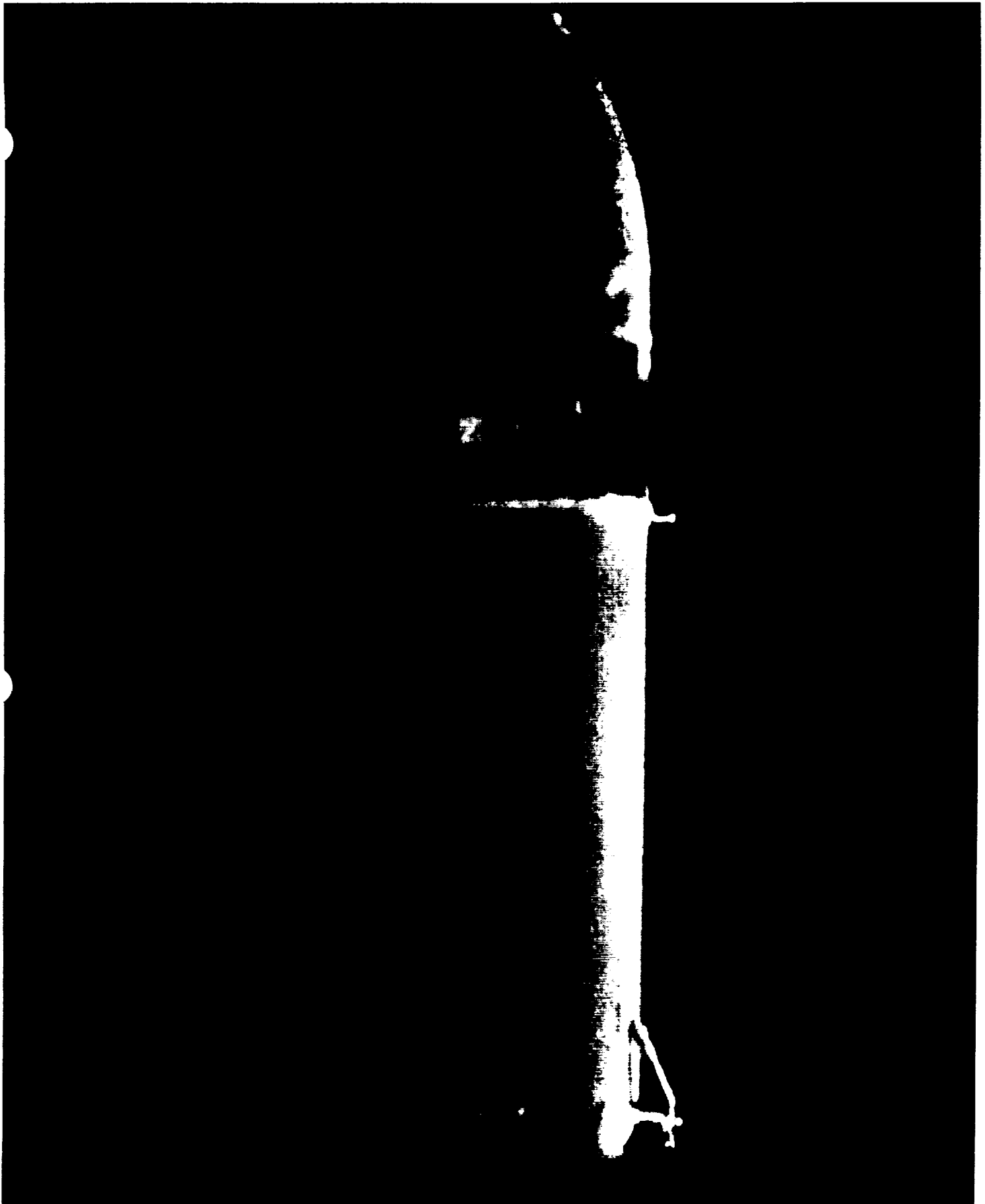
Orbiter performance in the Heading Alignment Circle (HAC) and final approach appeared nominal. Main landing gear deployment and touchdown was normal. Nose rotation and touchdown of the nose landing gear was smooth. Some tile damage on the Orbiter nose below the RH RCS thrusters was visible during the rollout. Infrared data of the Orbiter during final approach and touchdown showed no anomalies.



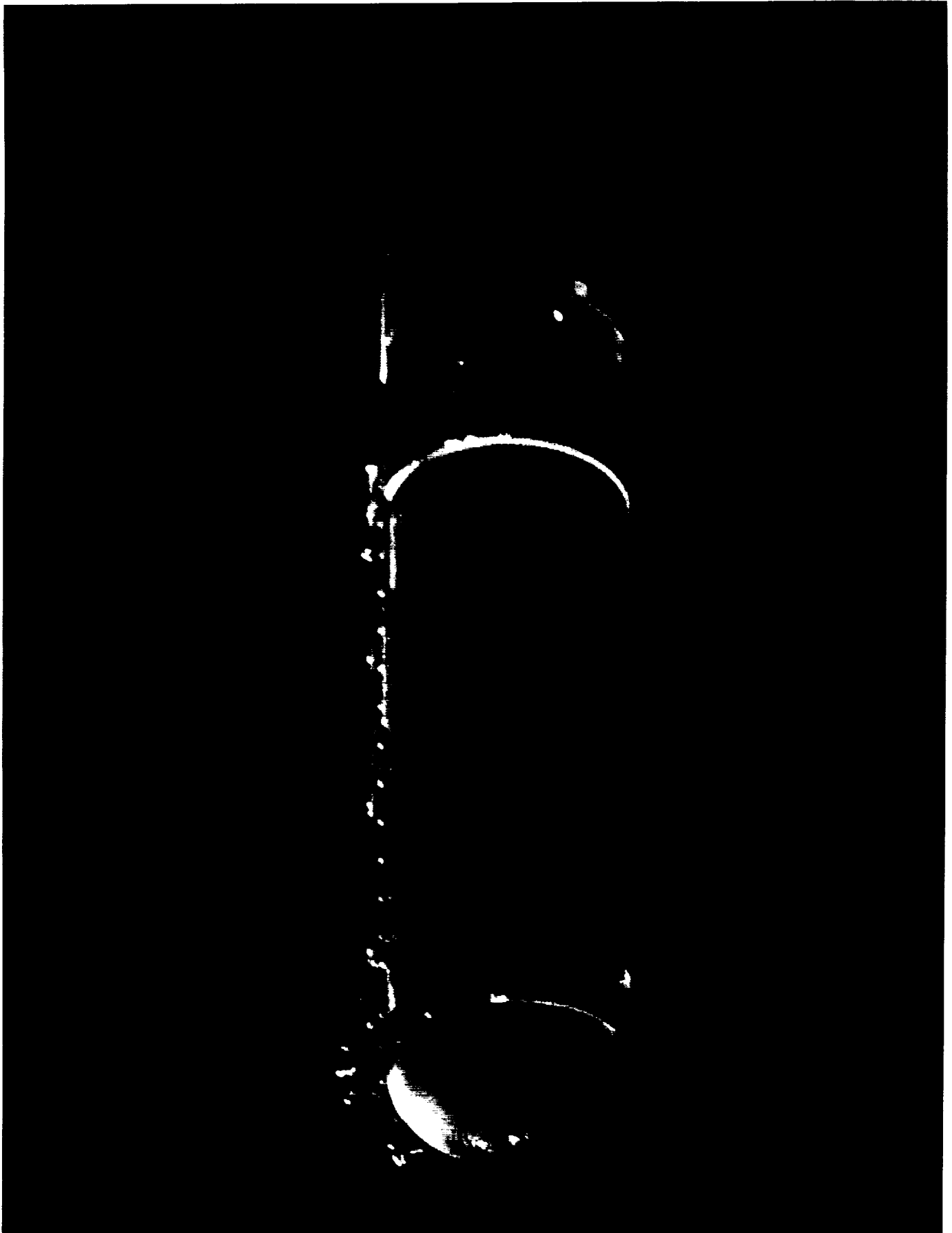
Exposure-adjusted views of the External Tank shortly after separation from the Orbiter show a conical shaped feature believed to be residual hydrogen venting from the LH2 ET/ORB umbilical 4-inch recirculation line interface area.



Faint trace of vapor (arrow) is believed to be venting of residual hydrogen from the flight umbilical carrier plate area shortly after the External Tank separated from the Orbiter.



View of the External Tank -Y side showed 4 divots in the LH2 tank-to-intertank flange closeout. There were no anomalies on the LO2 tank, intertank, and LH2 tank TPS acreage.



View of External Tank +Y side showed 6 divots in the LH2 tank-to-intertank flange closeout. Loss of TPS from this area has contributed to tile damage on the lower surface of the Orbiter on previous flights.

7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 26 March 1992 from 1430 to 1630 hours. From a debris standpoint, both SRB's were in excellent condition.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS but had 10 MSA-2 debonds over fasteners (Figure 4). The Hypalon paint was severely blistered and peeling the full circumference of the 395 ring frame and around the BSM's. The blisters averaged 2-3 inches in diameter and were generally ruptured. Layers of MTA adhered to the peeled Hypalon paint. PR PV6-214863 was taken to investigate the problem. All BSM aero heatshield covers were locked in the fully opened position. No hardware was missing from the frustum that could have caused the damage to RCC panel #10 on the Orbiter right wing leading edge.

The RH forward skirt exhibited no debonds or missing TPS (Figure 5). The phenolic plates on both RSS antennae were intact though the phenolic plate material on the +Z antenna was delaminated. The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. No hardware was missing that could have caused the damage to RCC panel #10 on the Orbiter right wing leading edge.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and all three aft booster stiffener rings appeared undamaged. A 6"x3" area of TPS on the forward side of the upper strut fairing at the separation plane was missing and the substrate was charred. The loss of TPS in this area may have occurred during strut separation. RTV-133 closeout around the outboard aft IEA covers did not adhere completely to the cover/ETA ring interface and may be an application problem. A PR was taken to investigate this occurrence. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing prior to water impact.

FIGURE 4. RIGHT SRB FRUSTUM

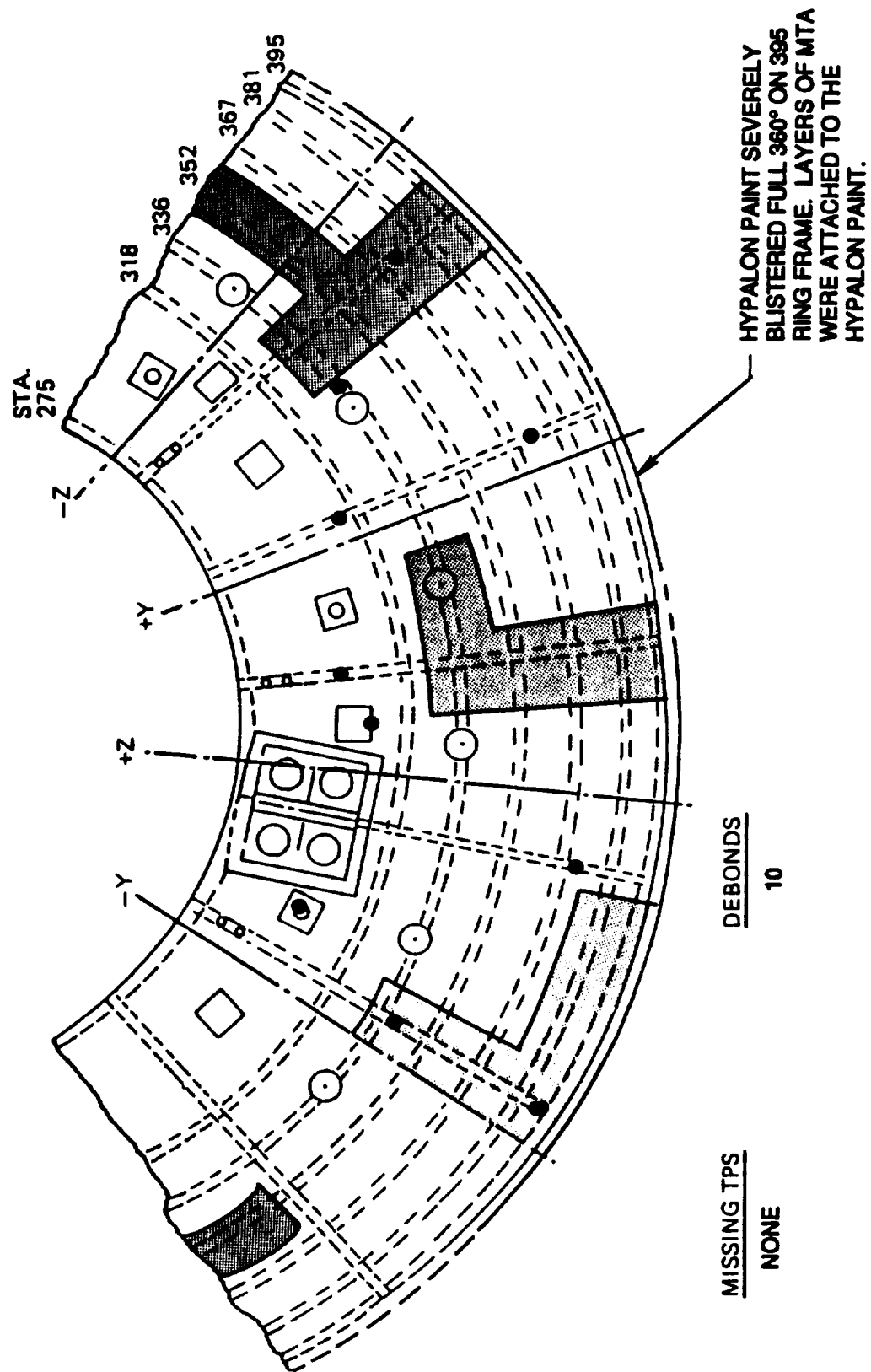


FIGURE 5. RIGHT SRB FWD SKIRT

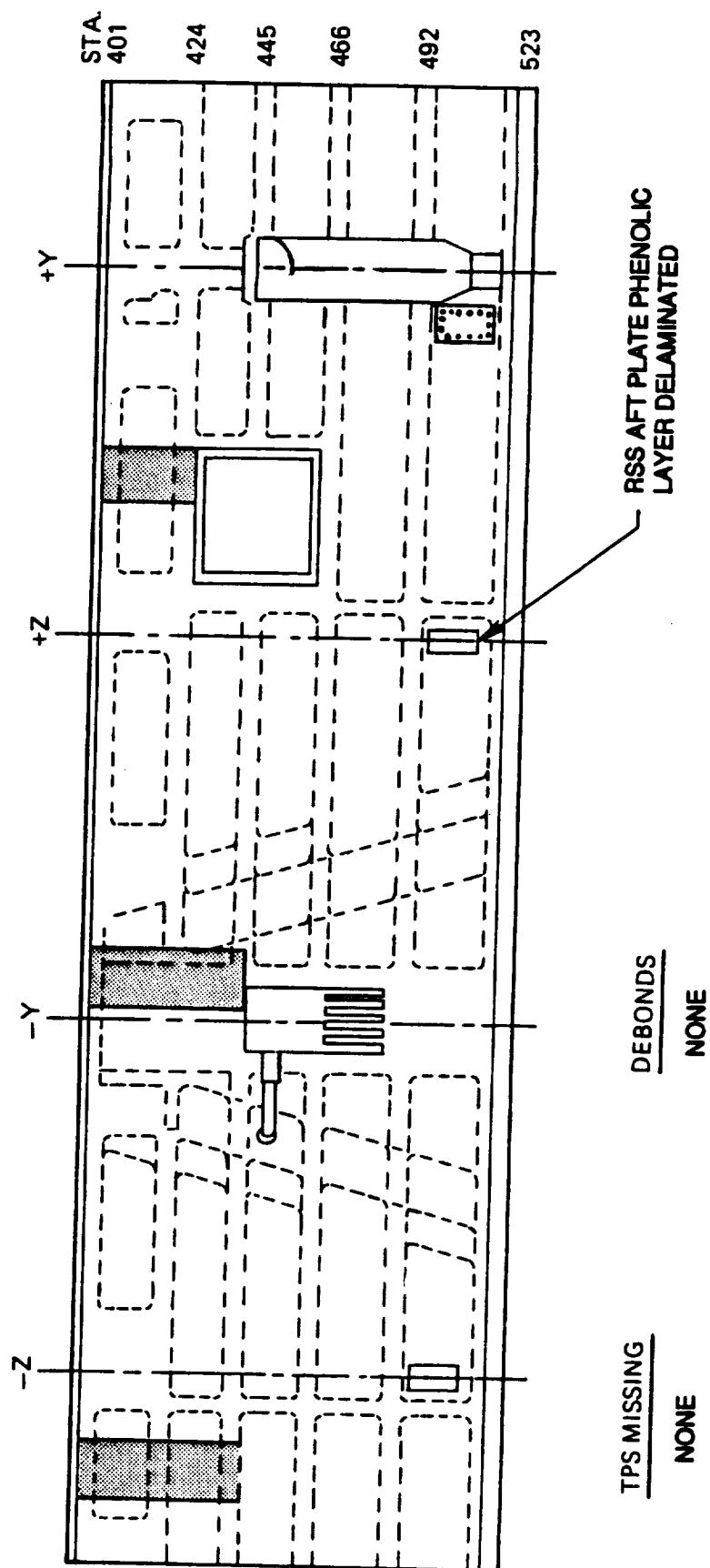
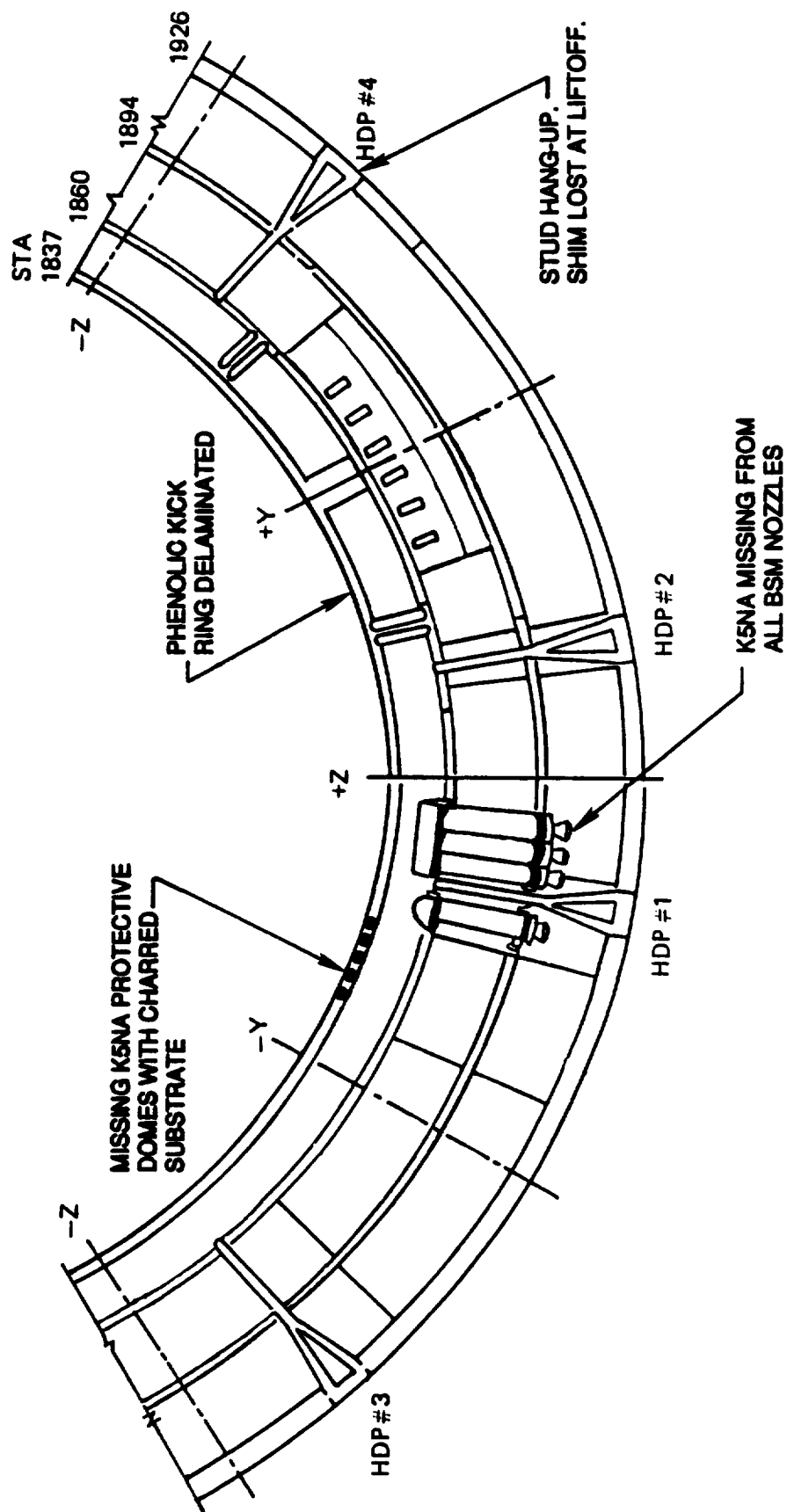
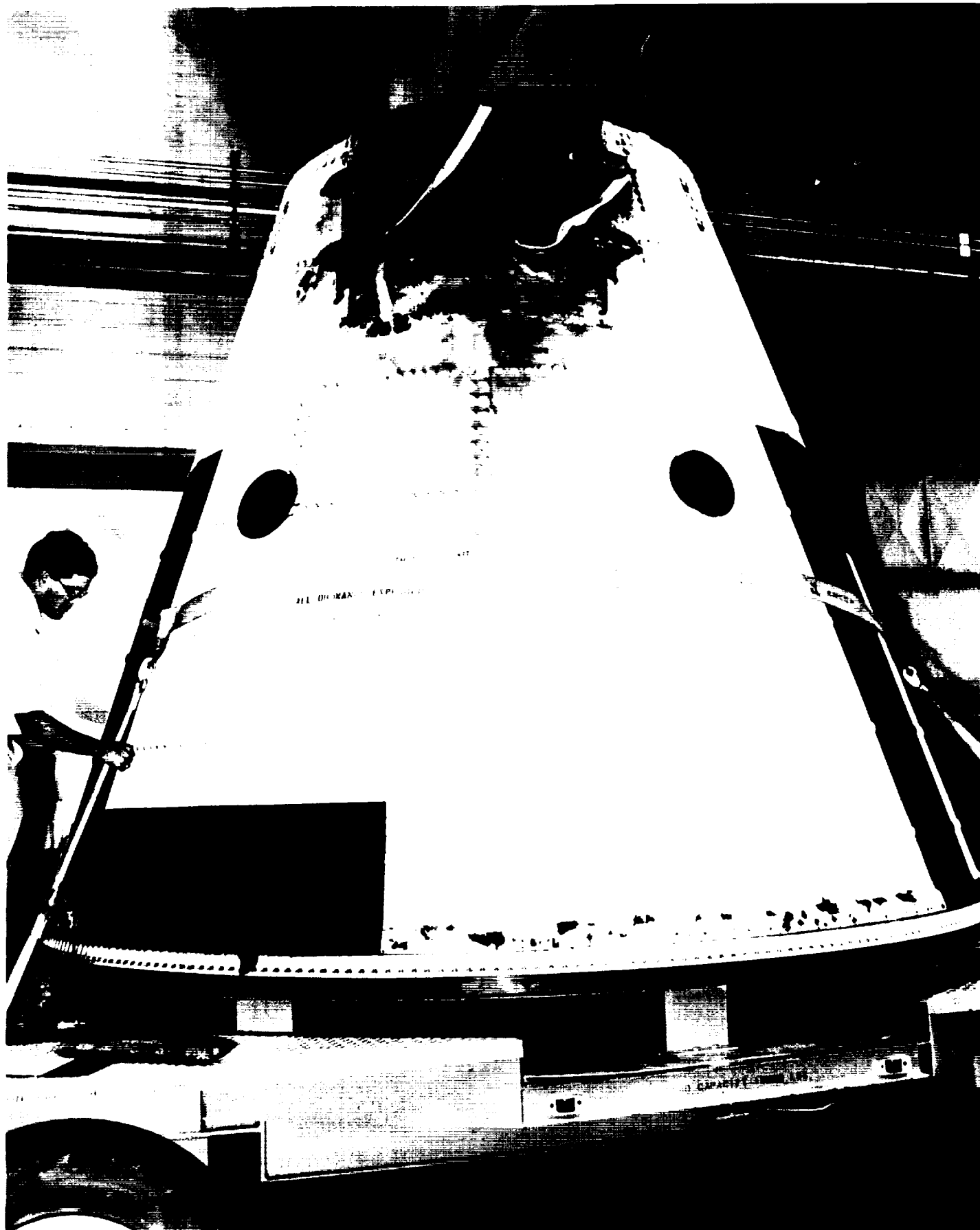


FIGURE 6. RIGHT SRB AFT SKIRT EXTERIOR TPS

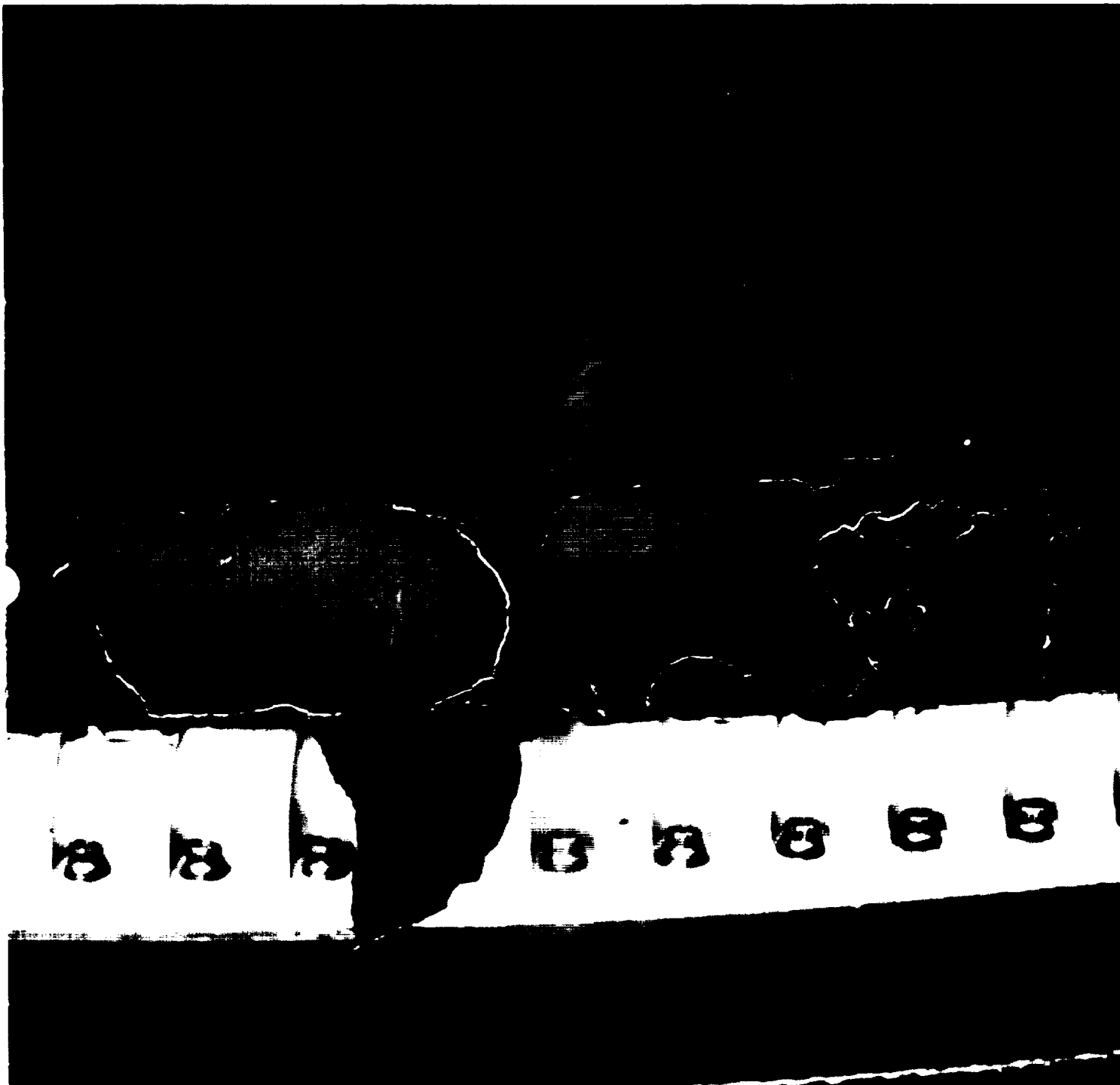


The phenolic material on the kick ring had delaminated. Several K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring prior to water impact (sooted substrate). K5NA was missing from all aft BSM nozzles (Figure 6). The aft skirt acreage TPS was generally in good condition. Squawk 45-011 was taken against two 1-inch gashes in the MSA-2 over fastener sealant two feet to the outboard side of the triple BSM housing. Slight sooting covered both areas. One theory suggested the gashes were caused by the same particles that had impacted the Orbiter RCC panel #10 on the right wing leading edge. Two MSA-2 samples were removed for evaluation, which revealed no charring or heat effects under the layer of sooting. The investigation concluded that the gashes occurred during SRB re-entry and descent and were not related to the Orbiter wing impact.

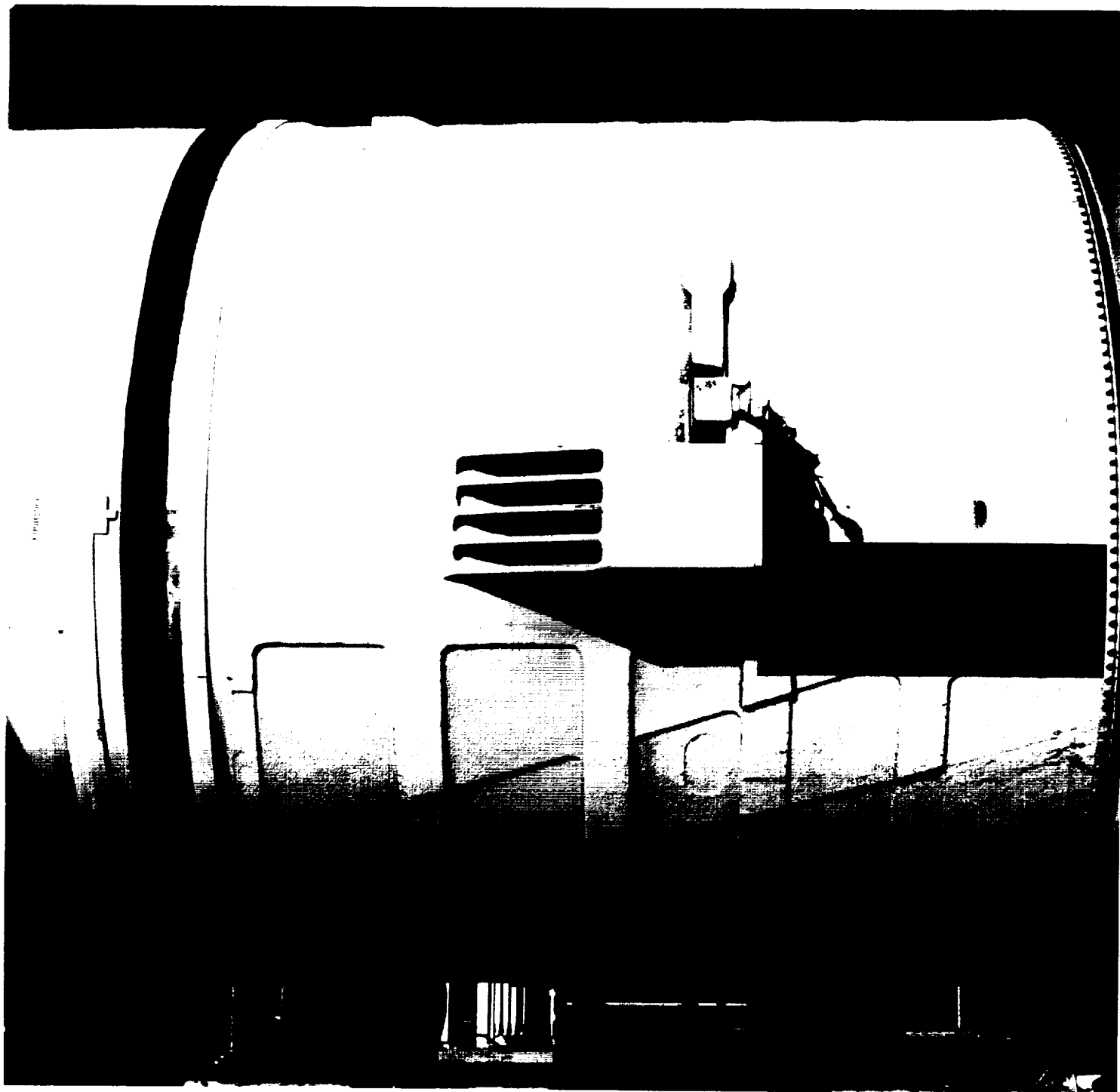
All Debris Containment System (DCS) plungers were seated properly. This was the sixth flight utilizing the optimized link. A stud hang-up had occurred on HDP #4 and the stud hole was broached. The HDP #4 EPON shim material was pulled off at liftoff by the stud (as observed in the film review).



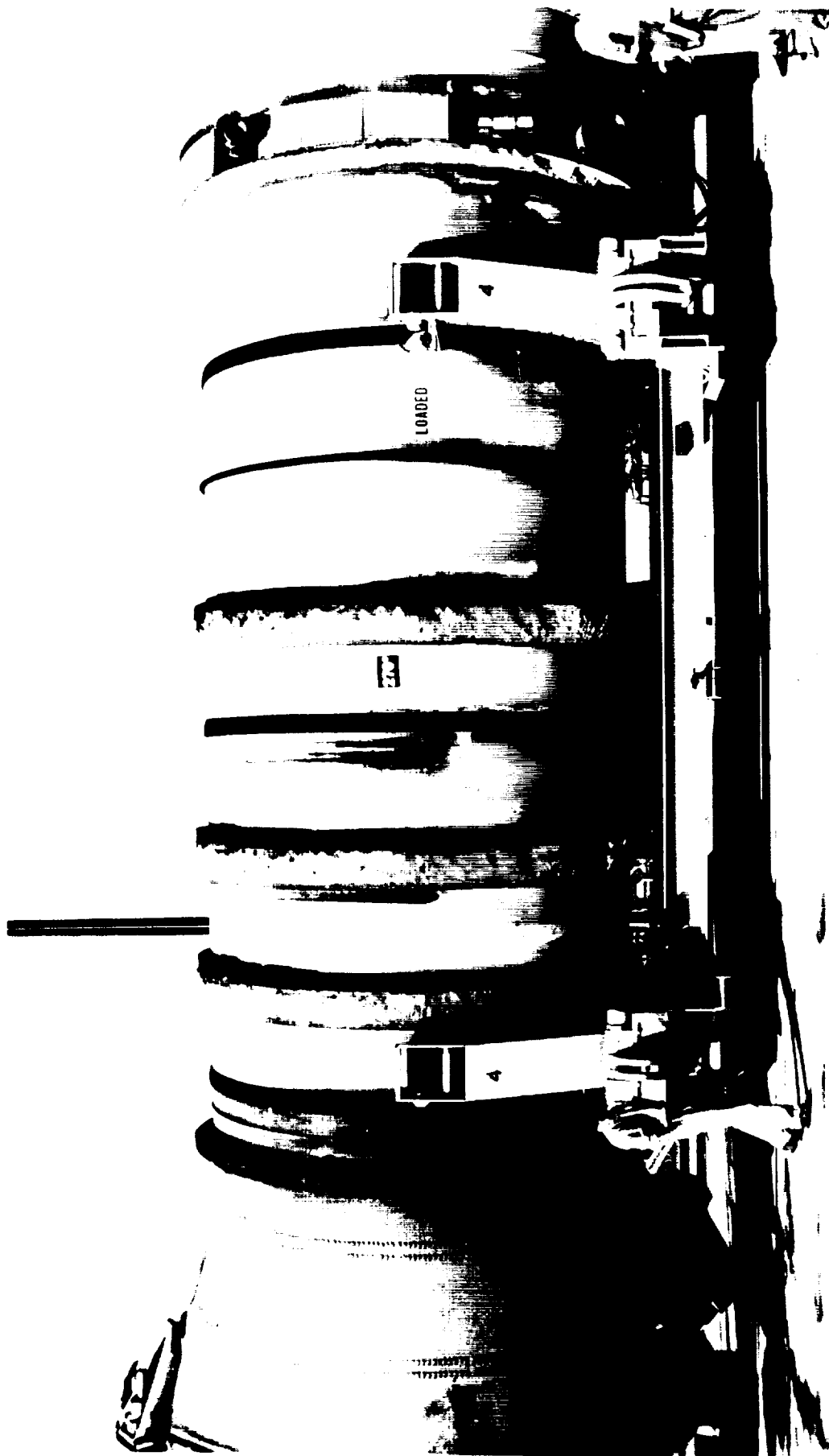
The RH frustum was missing no TPS but had 10 MSA-2 debonds over fasteners. The Hypalon paint was severely blistered and peeling the full circumference of the 395 ring frame and around the BSM area.



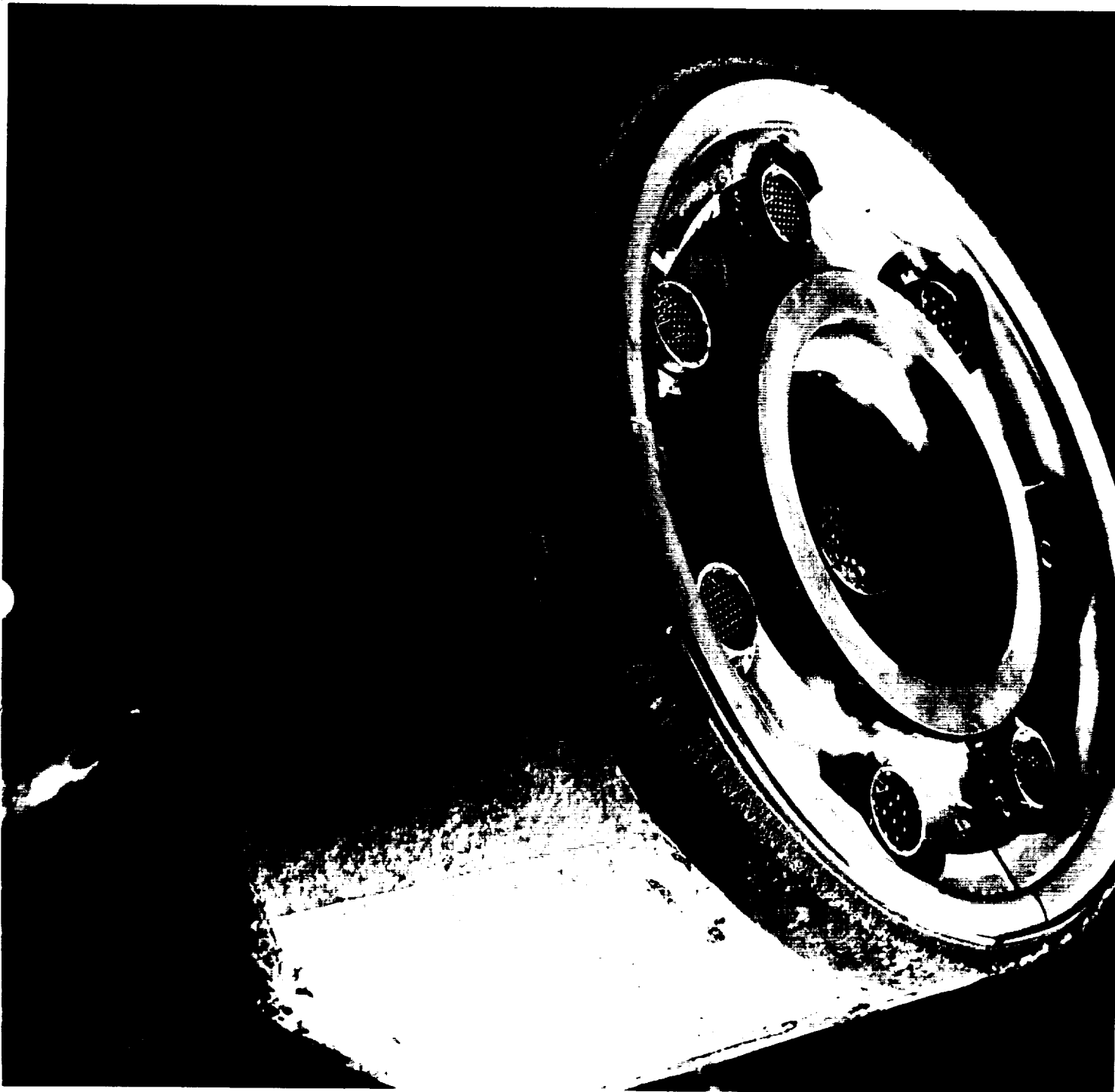
The Hypalon paint blisters averaged 2-3 inches in diameter and were generally ruptured. Layers of MTA adhered to the peeled Hypalon. Lab tests showed the blistering occurred during SRB re-entry.



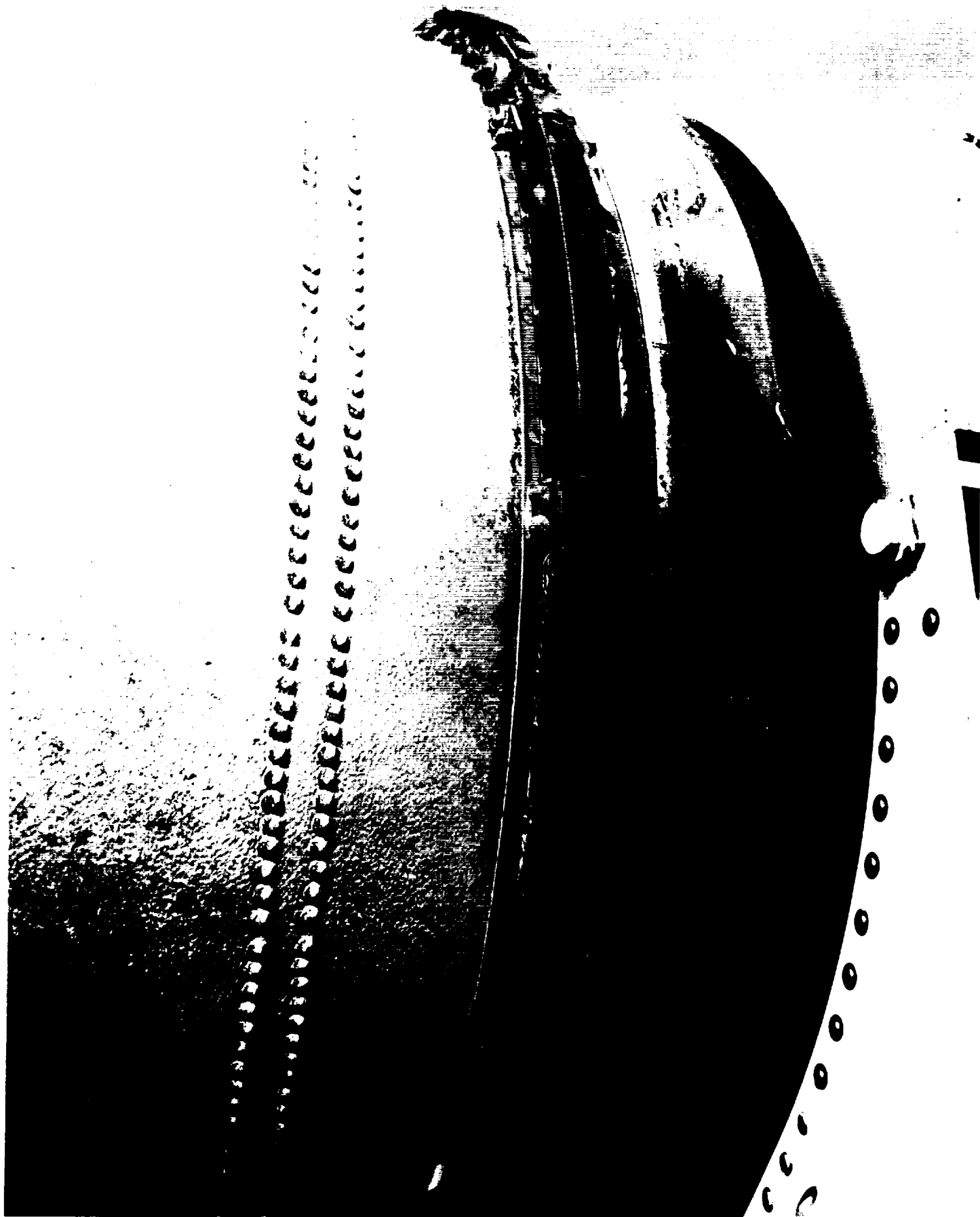
The RH forward skirt exhibited no debonds or missing TPS. Both RSS antenna phenolic plates were intact. No hardware was missing from the forward skirt that could have caused the damage to the RCC panel #10 on the Orbiter right wing leading edge.



Post flight condition of the RH aft booster. The aft skirt acreage TPS was sooted but in good condition. The ET/SRB aft struts, ETA ring, IEA, and all three aft booster stiffener rings appeared undamaged.



A 6"x3" area of TPS on the forward side of the upper strut fairing at the separation plane was missing and the substrate showed signs of heating. The loss of TPS may have occurred during strut separation.

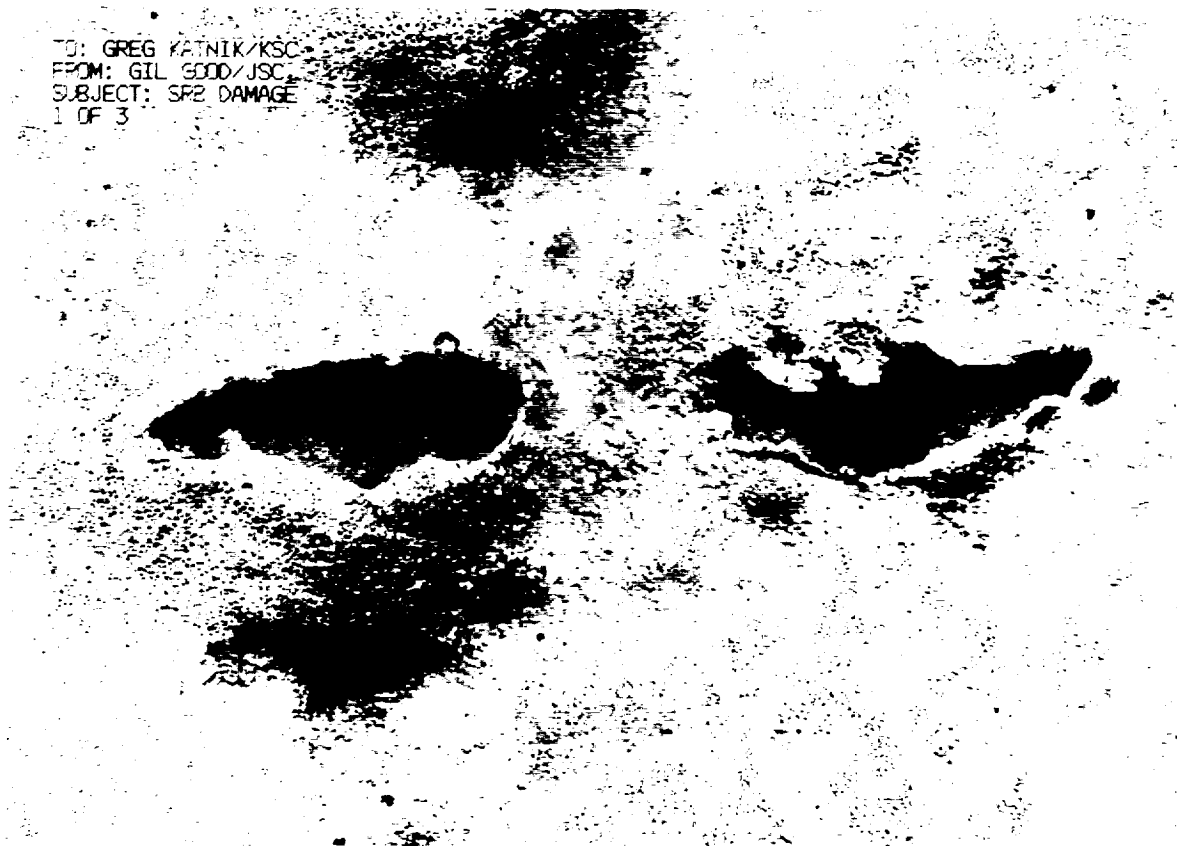


The phenolic material on the kick ring had delaminated. Several K5NA protective domes were lost from bolt heads on the aft side prior to water impact (sooted substrate).

TO: GREG KATNIK/JSC
FROM: GIL GOOD/JSC
SUBJECT: SRB DAMAGE
2 OF 3



TO: GREG KATNIK/JSC
FROM: GIL GOOD/JSC
SUBJECT: SRB DAMAGE
1 OF 3



Two 1-inch gashes in the aft skirt MSA-2 occurred during SRB re-entry and descent, according to lab tests, and were not related to the RCC panel #10 impact damage on the Orbiter wing.



A stud hang-up had occurred on HDP #4 and the stud hole was broached. The EPON shim material was pulled off at liftoff by the stud.

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS but had 12 MSA-2 debonds over fasteners. The largest debond measured 3"x2" and was located between the -Y and +Z axes near the 381 ring frame. There was minor localized blistering of the Hypalon paint (Figure 7). The BSM aero heat shield covers were locked in the fully opened position. However, three of the cover attach rings had been bent at the hinge by parachute riser entanglement.

The LH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact (Figure 8). The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. Minor blistering of the Hypalon paint occurred near the ET/SRB attach point.

The Field Joint Protection System (FJPS) closeouts were in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, IEA, ETA ring, and all three aft booster stiffener rings appeared undamaged. A 3"x0.5" area of TPS on the forward side of the upper strut fairing at the separation plane was missing and the substrate was charred. The loss of TPS in this area may have occurred during strut separation. RTV-133 closeout around the outboard aft IEA covers did not adhere completely to the cover/ETA ring interface and may be an application problem. A PR was taken to investigate this occurrence. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing prior to water impact.

Two K5NA protective domes were missing from bolt heads on the aft side of the phenolic kick ring prior to water impact (charred substrate). K5NA was missing from all aft BSM nozzles (Figure 9). The aft skirt acreage TPS was in good condition.

The HDP #7 Debris Containment System (DCS) plunger was not seated and was obstructed by a frangible nut half. This was the sixth flight utilizing the optimized link. There was no sign of broaching in any of the stud holes. Twenty percent of the HDP #8 EPON shim material was lost prior to water impact.

FIGURE 7. LEFT SRB FRUSTUM

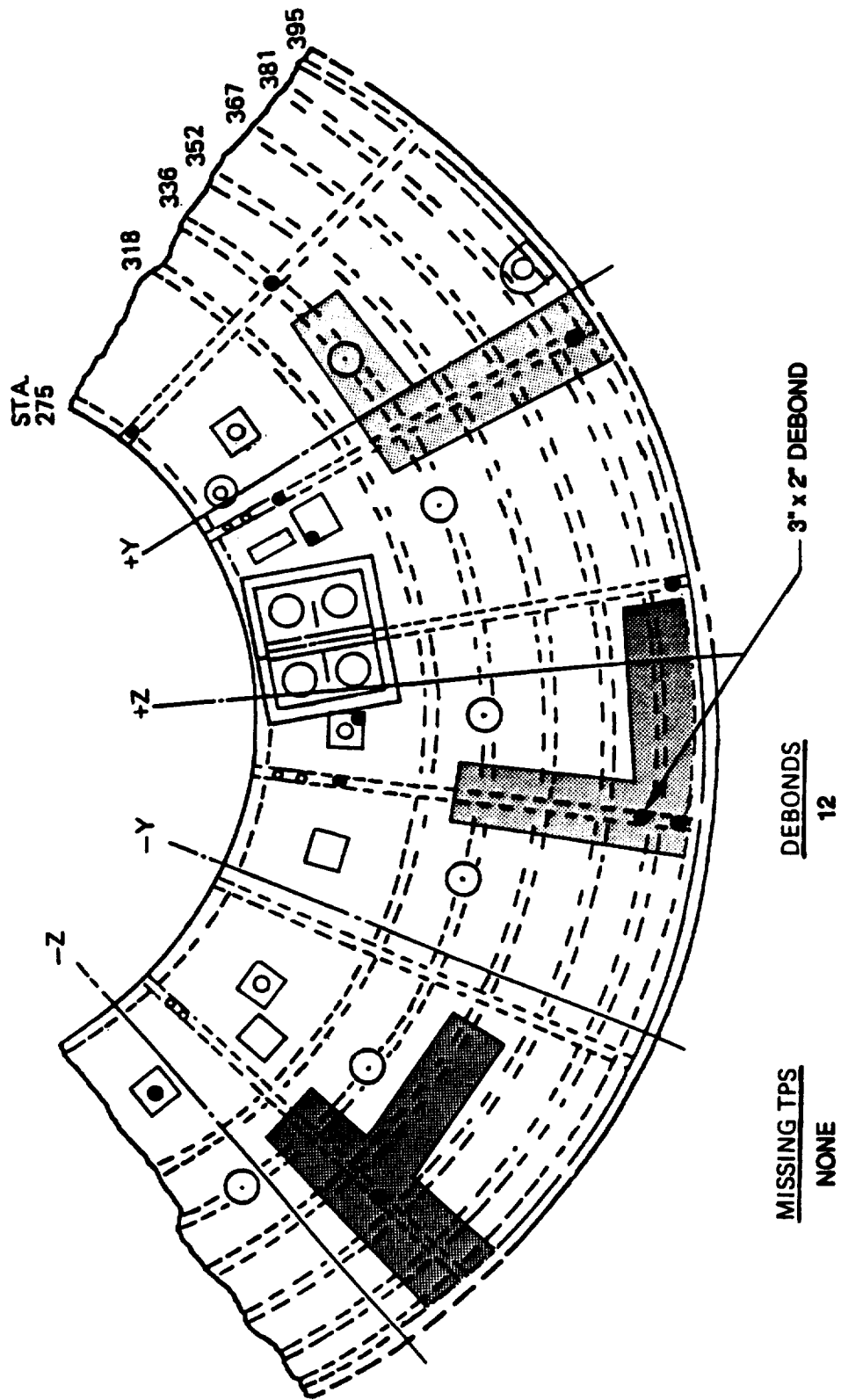


FIGURE 8. LEFT SKIRT AND SKIRT

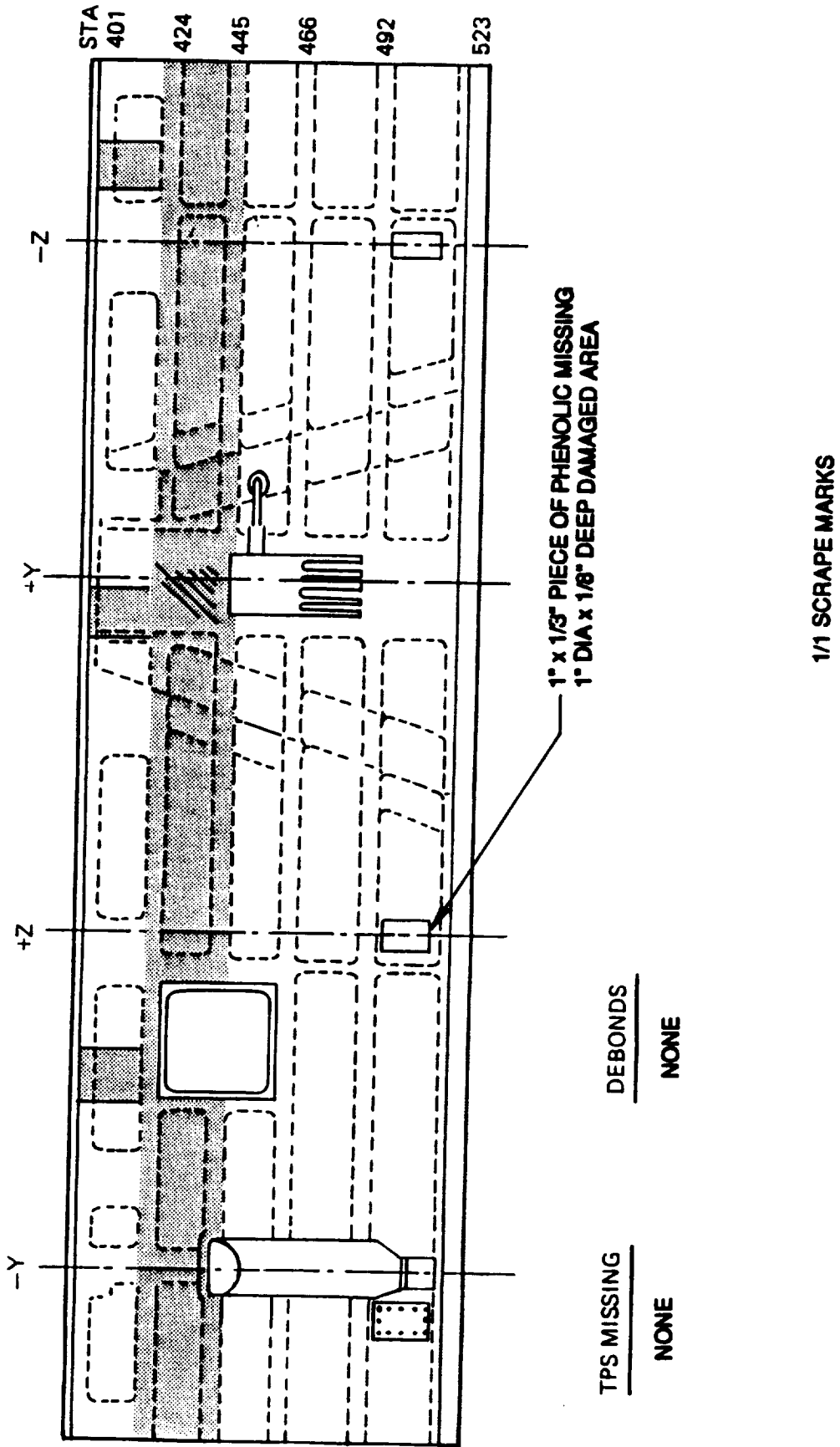
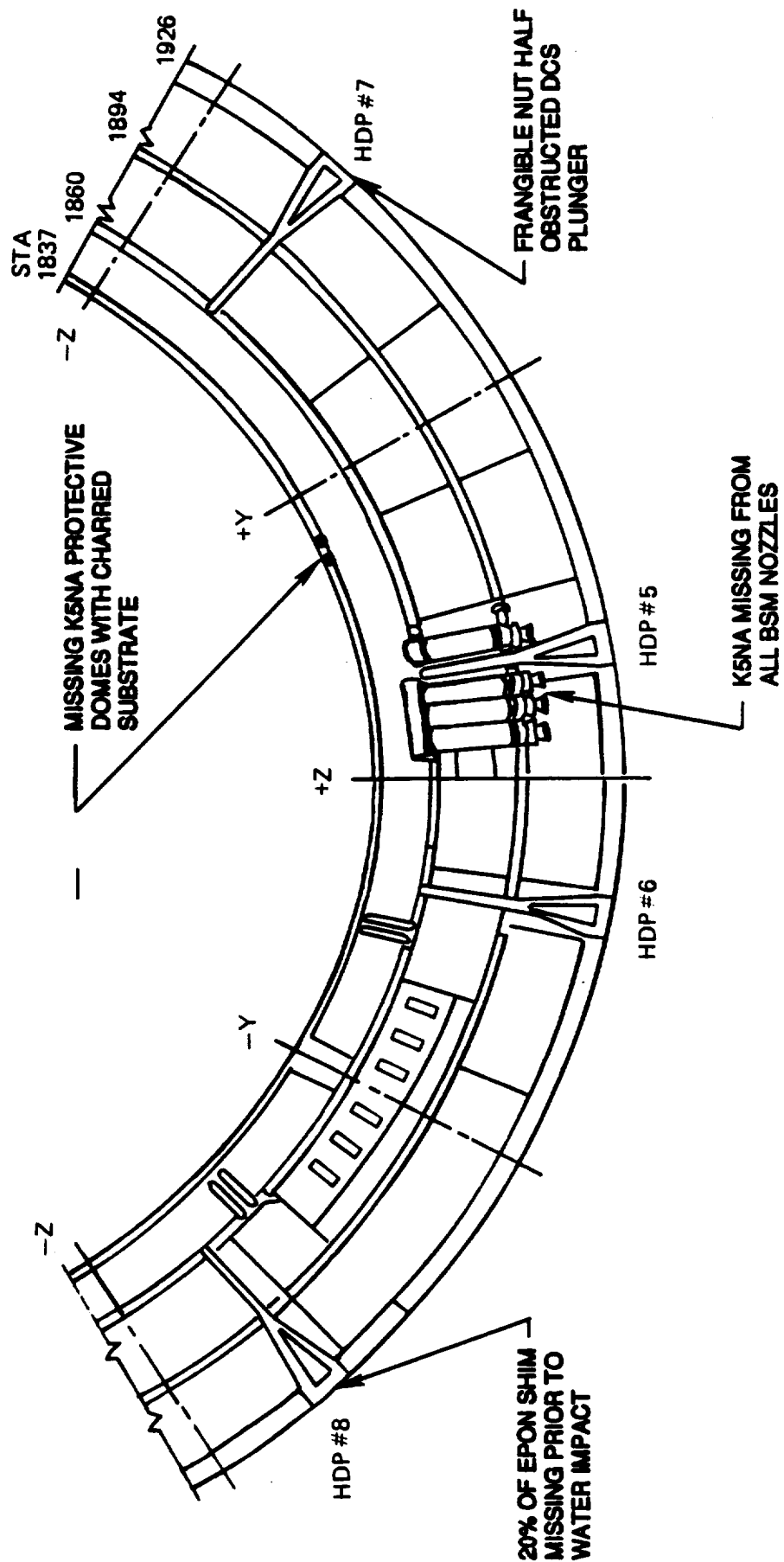
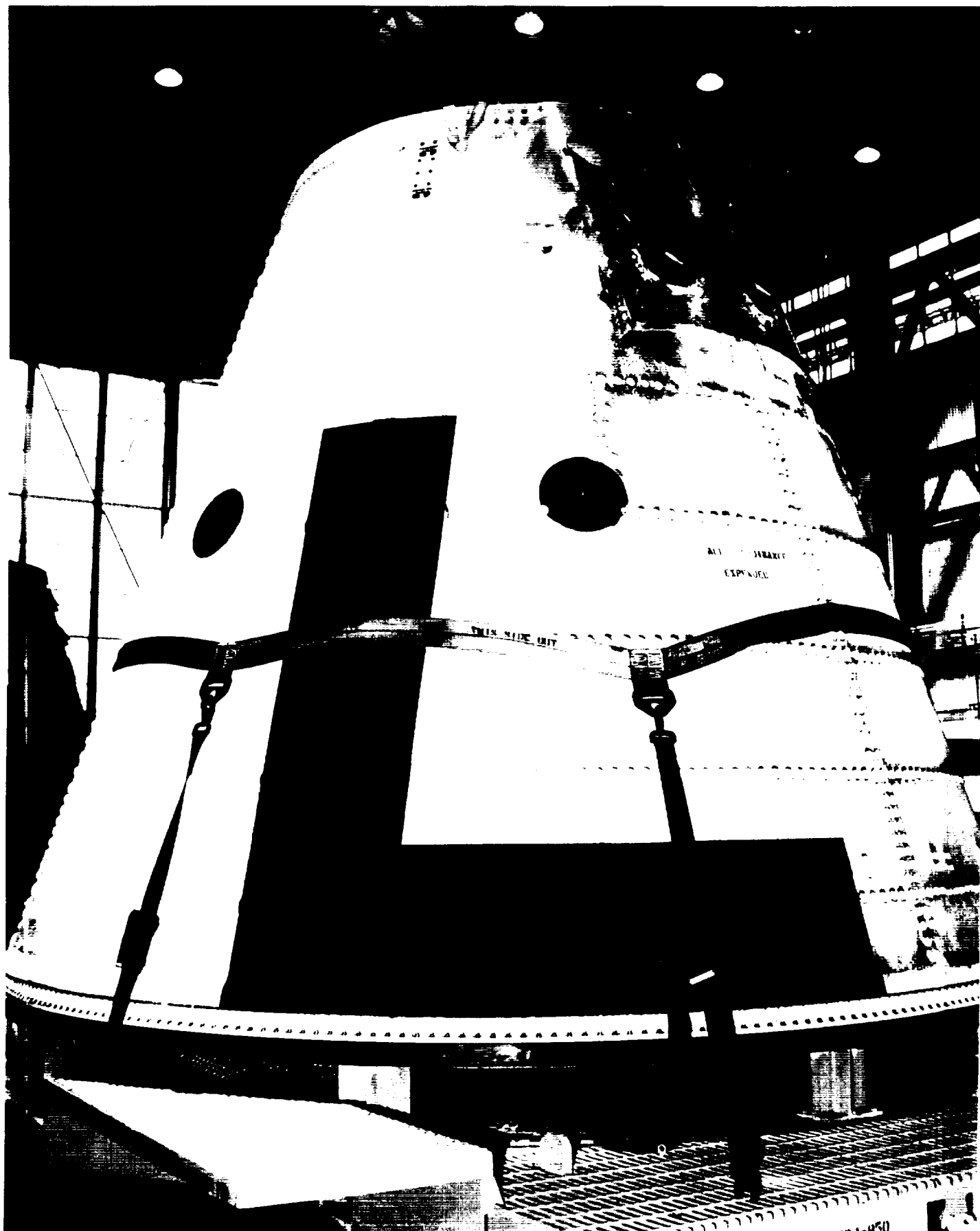
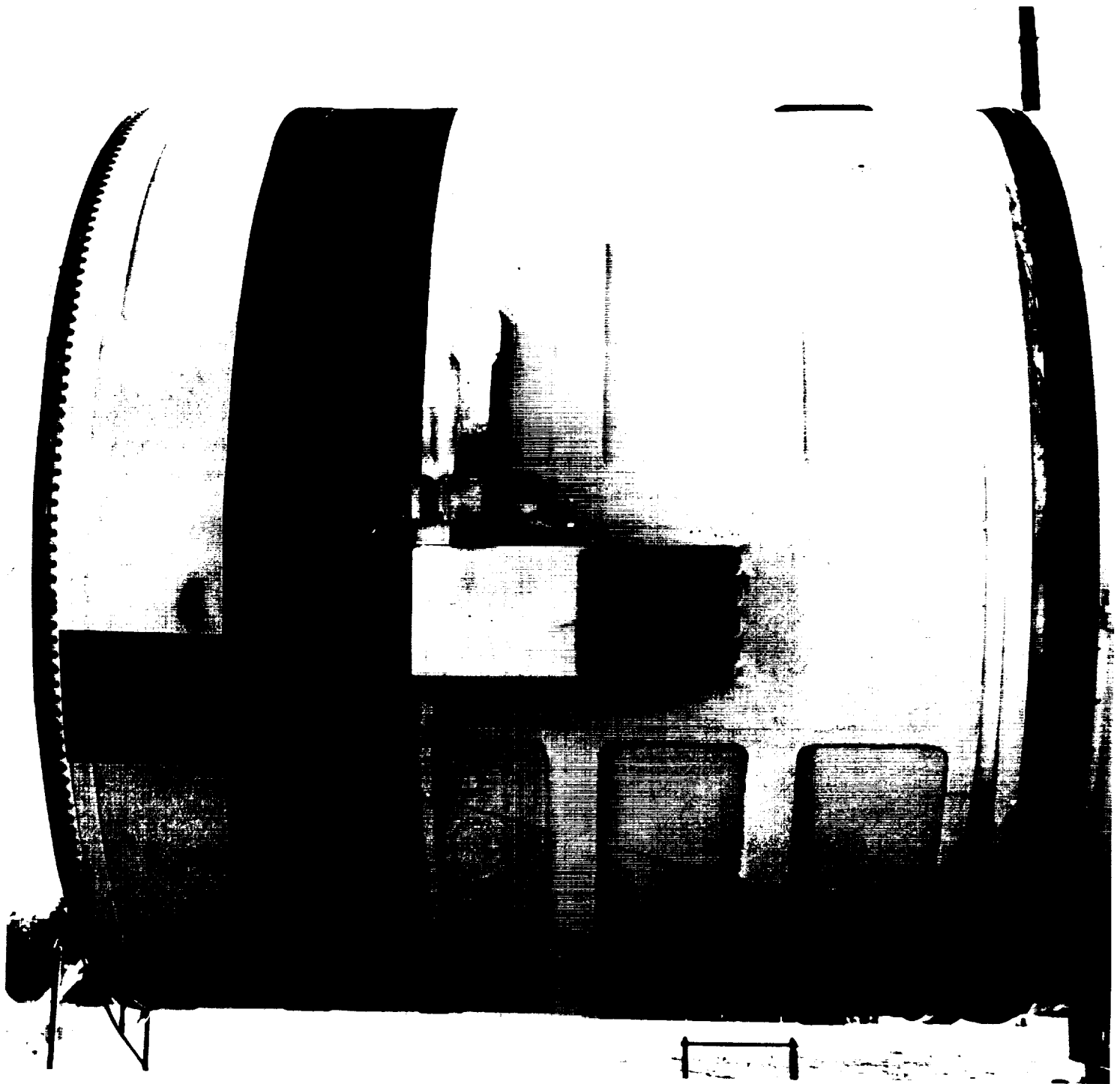


FIGURE 9. LEFT SRB AFT SKIRT EXTERIOR TPS

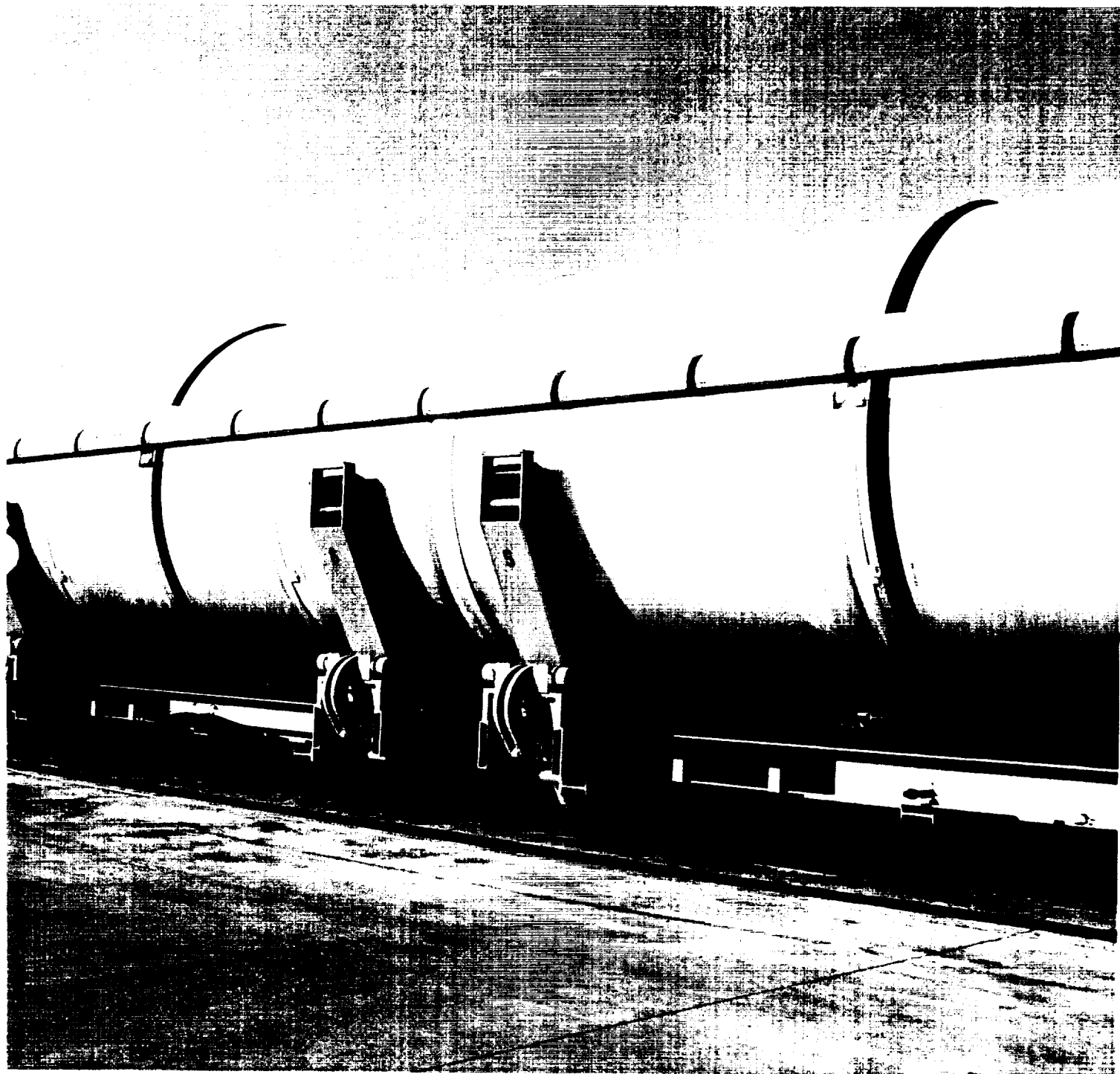




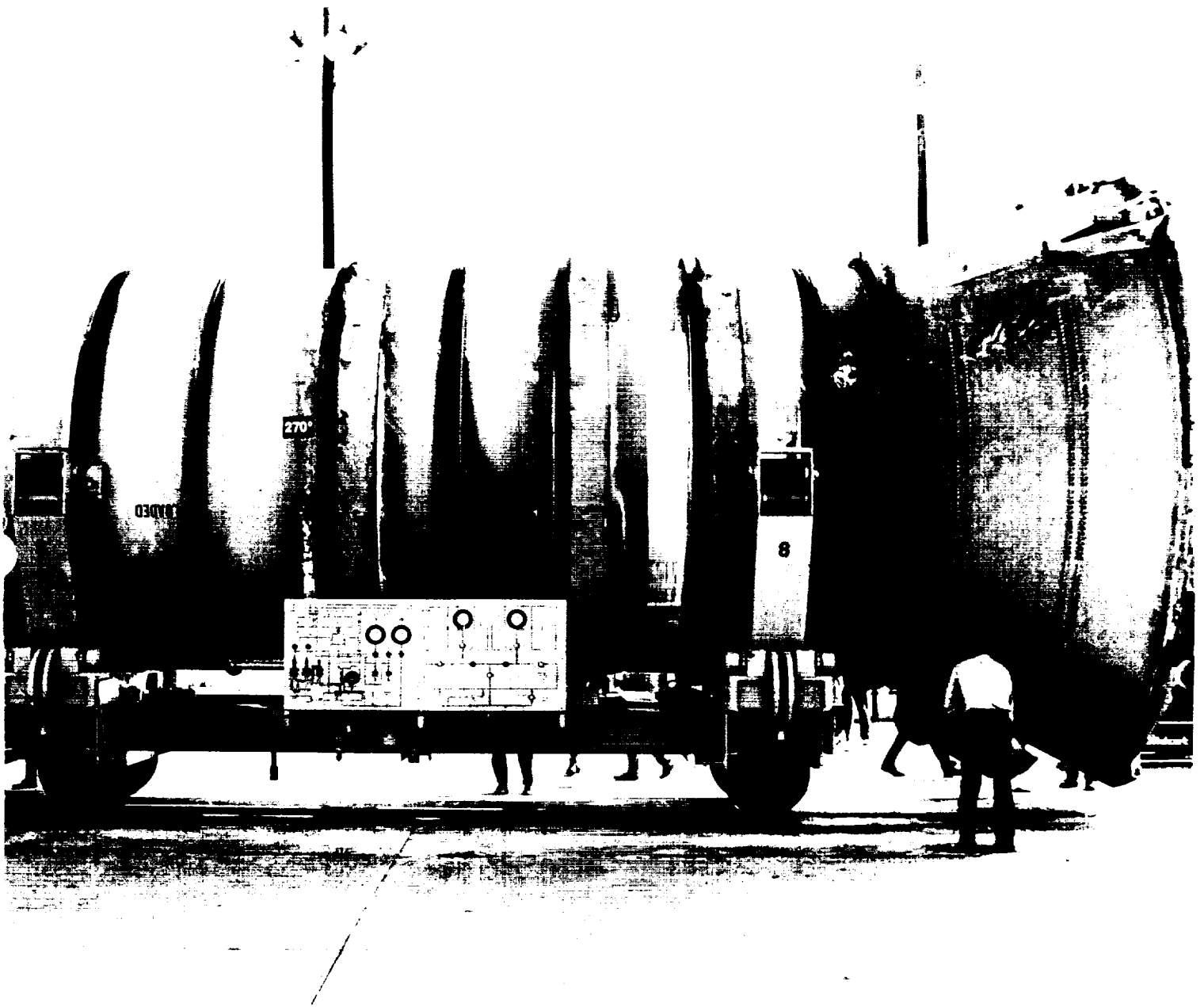
The LH frustum was missing no TPS but had 12 MSA-2 debonds over fasteners. The largest debond measured 3"x2" and was located between the -Y and +Z axes near the 381 ring frame.



The LH forward skirt exhibited no MSA-2 debonds or missing TPS.



Post flight condition of the segment cases, factory joints,
and field joints was normal



////////////////////////

Post flight condition of the LH aft booster/aft skirt. The aft skirt acreage TPS was sooted but generally in good condition. The ET/SRB aft struts, IEA, ETA ring, and all three aft booster stiffener rings appeared undamaged.

7.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 87 percent and individual holddown post retention percentages as listed:

HDP #	% of Nut without 2 large halves	% of Ordnance fragments	% Overall
1	99	99	99
2	99	98	99
3	99	94	99
4	99	87	97
5	99	99	99
6	99	99	99
7	8	13	8
8	99	99	99

STS-45 was the sixth flight to utilize the new "optimized" frangible links in the holddown post DCS's. The link was designed to increase the DCS plunger velocity and improve the seating alignment while leaving the stud ejection velocity the same. The design was intended to prevent ordnance debris from falling out of the DCS yet not increase the likelihood of a stud hang-up. According to NSTS-07700, the Debris Containment System should retain a minimum of 90 percent of the ordnance debris. Overall percentages of retention for the five previous flights utilizing the "optimized" link are:

HDP #	BI-044 STS-40	BI-045 STS-43	BI-046 STS-48	BI-047 STS-44	BI-048 STS-42
1	99%	98%	99%	99%	99
2	99%	31%	88%	99%	98
3	38%	99%	99%	99%	99
4	99%	99%	99%	99%	99
5	23%	99%	58%	99%	99
6	99%	99%	99%	99%	99
7	62%	99%	99%	99%	99
8	99%	99%	99%	99%	99
TOTAL	77%	90%	92%	99%	99%
Debris Loss	58 oz	25 oz	19 oz	negl	negl

MSFC/USBI performed an analysis (ref No. M&P-3033-045-92) on samples of the RH frustum blistered Hypalon paint and adhering MTA layers. The Hypalon blistering has been limited to those areas with an MTA substrate. Although the blistering had not occurred on the LH frustum, the investigation found both of the frustums had been processed at approximately the same time and in the same thermal environment. Measurements of the Hypalon paint applied to the RH frustum MTA was 13 mils thick (8 mils minimum is required) compared to an average thickness of 35

mils on the RH frustum MSA-2 acreage and 55 mils average thickness on the LH frustum MTA and MSA-2 acreage. No anomalies were found with the Hypalon constituents or application procedures. The report concluded the RH frustum MTA exhibited elevated levels of thermal decomposition and gas evolution (in the thermal environment of re-entry/descent), which could not be contained by the relatively thin layer of Hypalon and resulted in the blistered condition.

The RTV-133 closeout around the outboard aft IEA covers had not adhered completely to the cover/ETA ring interface. A Problem Report determined the adhesion anomaly was caused by the method of application. Deviations to the application procedure were written and the closeouts on the STS-49 vehicle were reworked prior to launch.

SRB Post Launch Anomalies are listed in Section 10.

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-104 (Atlantis) was conducted on April 2 and 3, 1992, at the Kennedy Space Center Shuttle Landing Facility (SLF) on runway 33 and in the Orbiter Processing Facility Bay #1. This inspection was performed to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 172 hits, of which 22 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 30 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates that the total number of hits is greater than average and the number of hits one inch or larger is near average. Figures 10-13 show the TPS debris damage assessment for this mission.

The Orbiter lower surface sustained a total of 122 hits, of which 18 had a major dimension of one inch or greater. Thirty-seven hits, of which seven had a major dimension of one inch or greater, were located along the forward one-quarter of the lower right surface. Some of these hits may have been caused by ice from the External Tank LO2 feedline brackets and bellows. One damage site in tile V070-391015-211 contained an embedded debris particle. A chemical analysis was performed on this particle and the results are presented in Section 9.0.

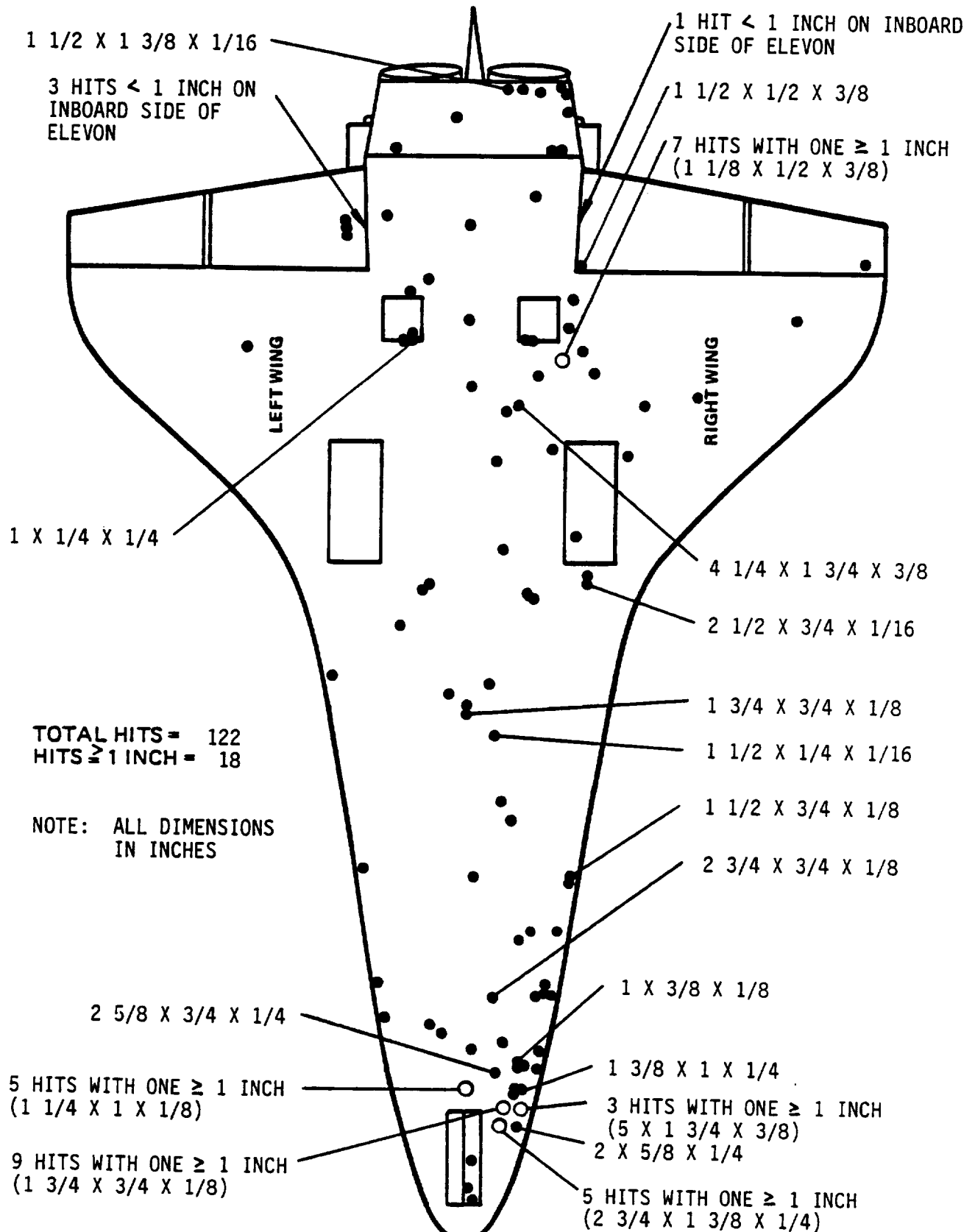
The following table shows the STS-45 Orbiter debris damage by area:

	<u>HITS > 1"</u>	<u>TOTAL HITS</u>
Lower surface	18	122
Upper surface	1	41
Right side	0	2
Left side	0	0
Right OMS Pod	2	2
Left OMS Pod	1	5
TOTALS	22	172

No TPS damage was attributed to material from the wheels, tires, or brakes. The main landing gear tires were considered to be in good condition for a KSC concrete runway landing.

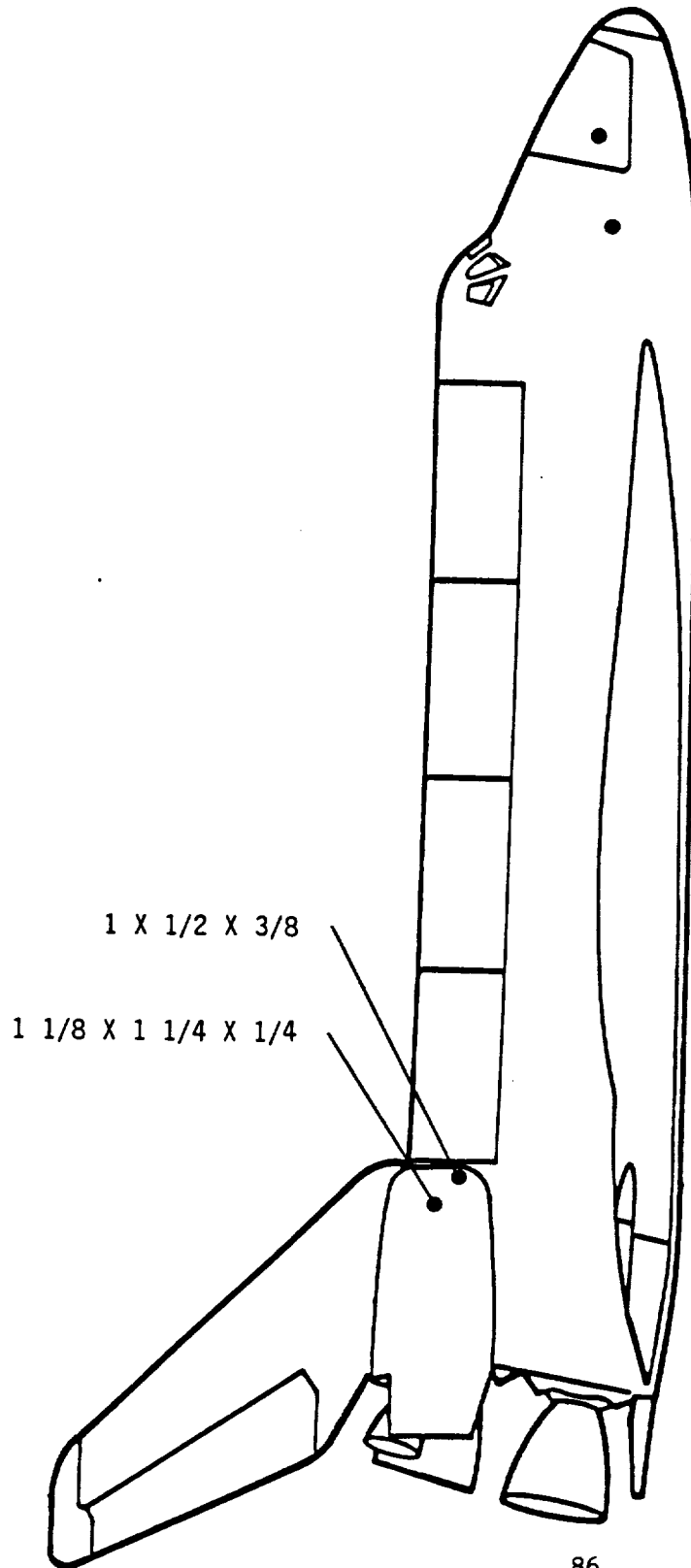
STS-45

FIGURE 10. DEBRIS DAMAGE LOCATIONS



STS-45

FIGURE 11. DEBRIS DAMAGE LOCATIONS

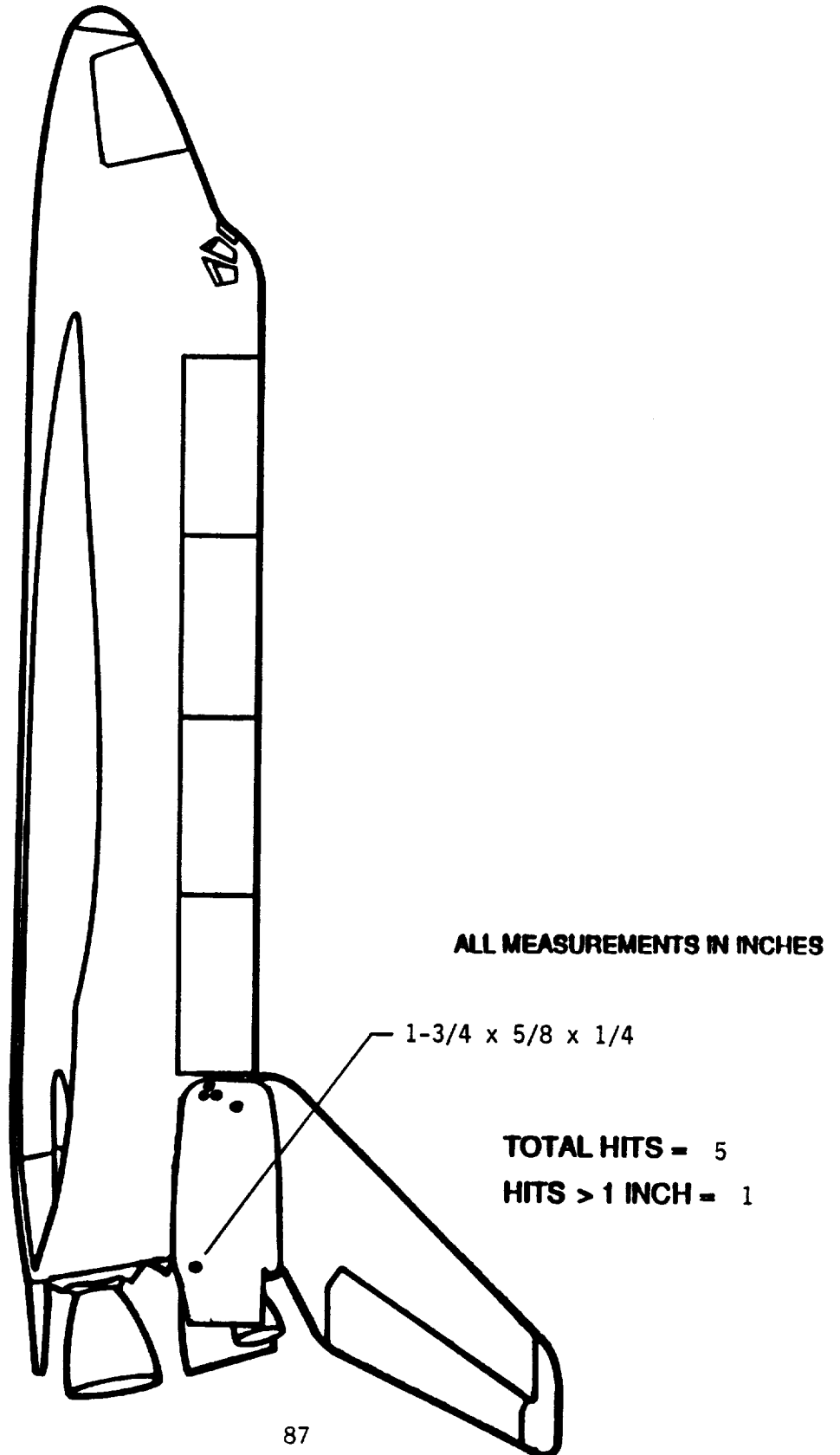


NOTE: ALL MEASUREMENTS
IN INCHES

TOTAL HITS = 4
HITS \geq 1 INCH = 2

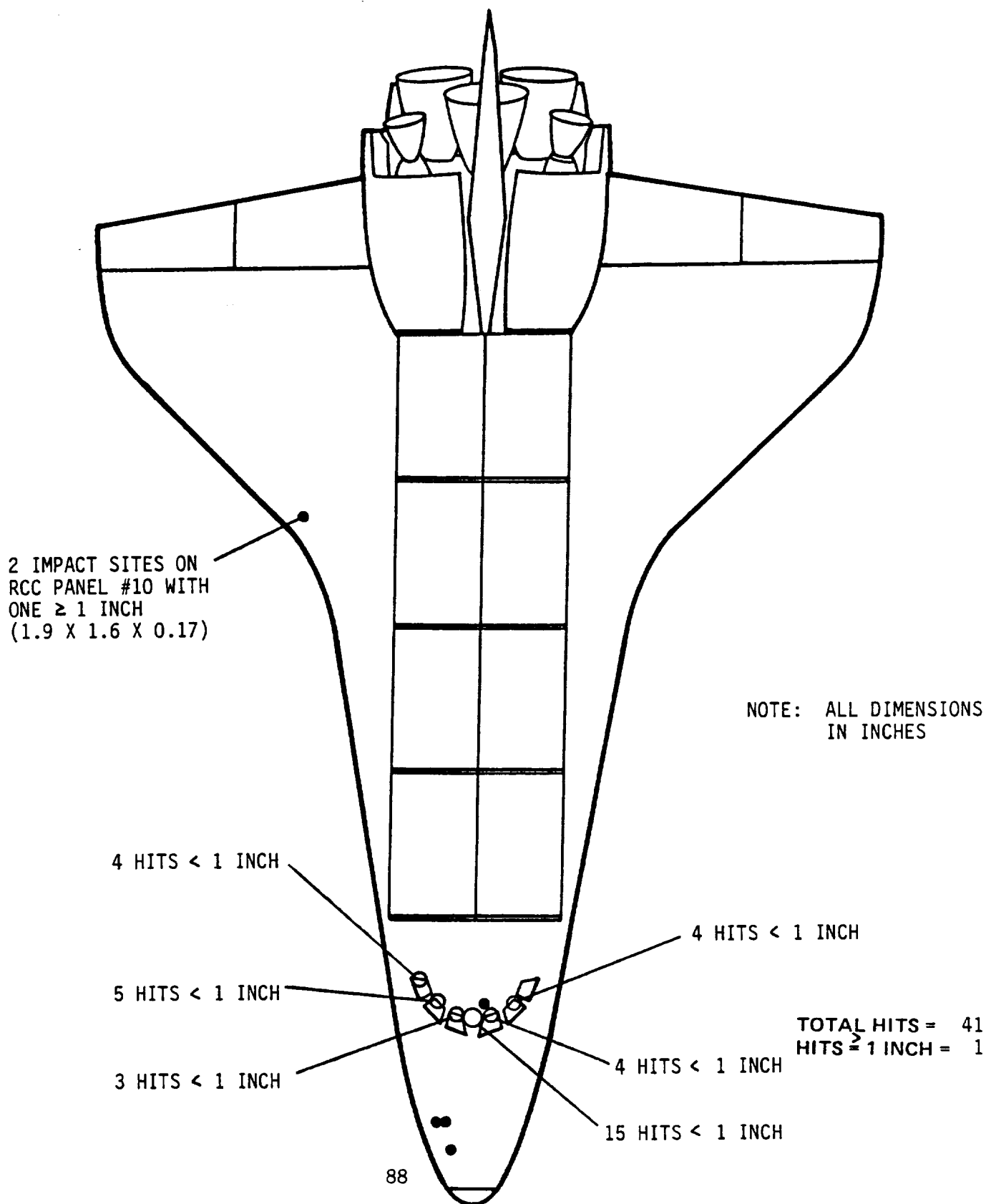
STS-45

FIGURE 12. **DEBRIS DAMAGE LOCATIONS**



STS-45

FIGURE 13. DEBRIS DAMAGE LOCATIONS



An expended NASA Standard Initiator (NSI) detonator with an attached connector coupling ring from the aft umbilical separation system fell to the runway when the RH (LO2) ET umbilical door was opened. A coupler retaining ring from the same detonator was found adhering to some RTV on the inner surface of the RH umbilical door. PR PYR-4-12-0151 was taken by Pyro engineering to document these anomalies. ET/Orbiter (EO) separation ordnance device plungers 1 and 2 appeared to have functioned properly. However, the EO-3 plunger was obstructed by a detonator booster and frangible nut half (PR PYR-4-12-0150). Because of the obstruction of the EO-3 plunger, a detonator booster from the separation assembly was allowed to escape and was found in the ET door hinge cavity (PR PYR-4-12-0150, Page 1A).

Damage to the base heat shield tiles was less than average. The closeout blanket on SSME #3 was badly torn and frayed from 7:30 to 12:00 o'clock. Three of the sacrificial patches from this area were missing. Two of these missing patches were recovered near Pad A during the post launch debris inspection. The SSME #2 blanket was in good condition although the sacrificial patch covering the splice at 12:00 o'clock was missing. The same type of sacrificial patch on the SSME #1 blanket from 5:00 to 6:00 o'clock exhibited significant fraying.

Two impact damage sites were present on the upper surface of the right wing RCC panel #10 (reference PR-STR-04-12-2504). Laboratory testing could not conclusively define the impact speed, impact direction, and time of impact (ascent, on-orbit, etc.).

Orbiter windows #3 and #4 exhibited light hazing with a few small streaks. Chemical analysis was performed on samples taken from all windows (ref Figure 14 and Section 9.0).

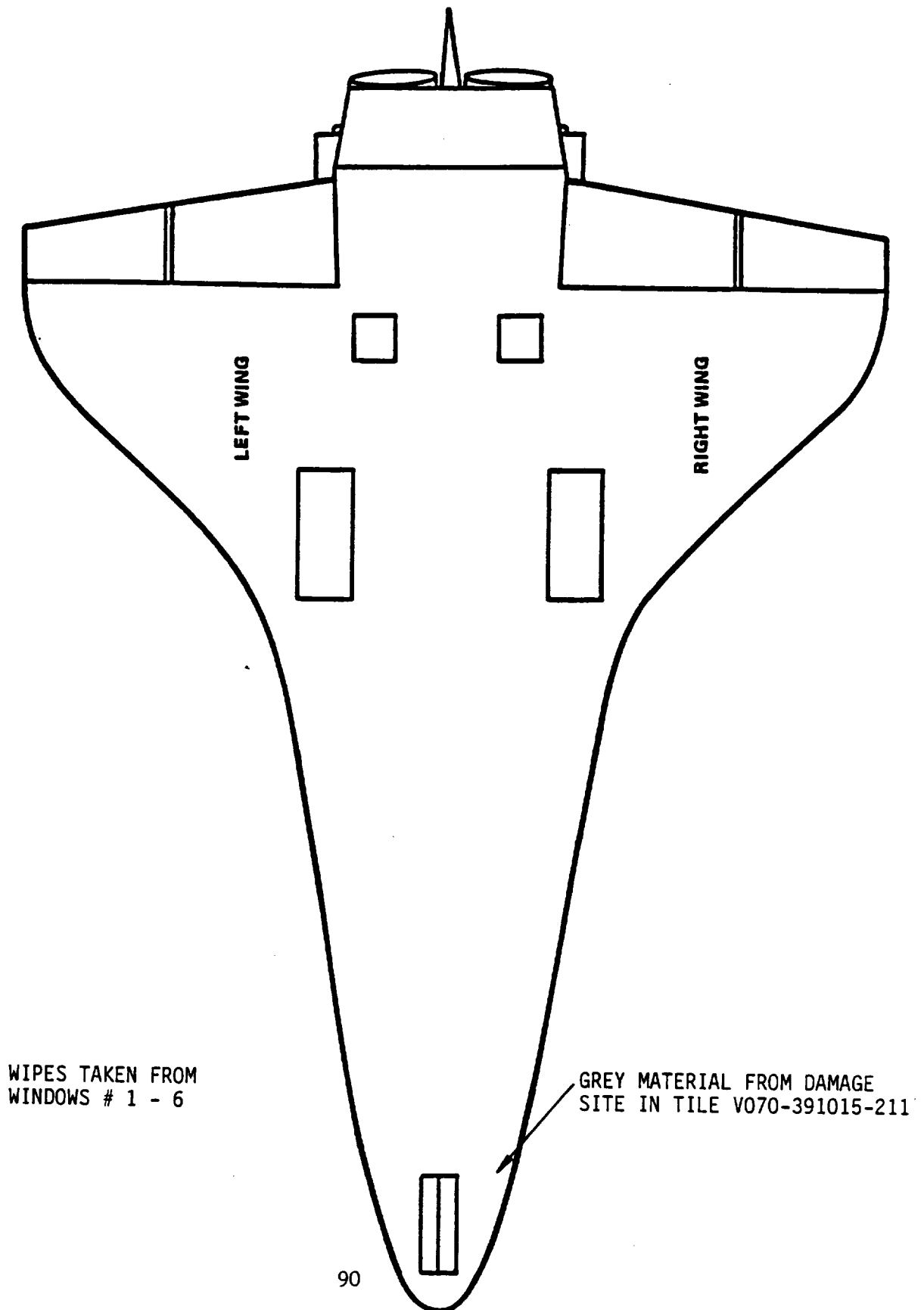
A greater than usual number of damage sites occurred on the perimeter tiles of Orbiter windows #2 through #6 and on the tiles between windows #3 and #4. Most of the impact sites were only surface coating losses or were no more than 1/16th inch deep. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles or by exhaust products from the SRB booster separation motors.

A portable Shuttle Thermal Imager (STI) was used to measure the surface temperature of three areas on the Orbiter TPS after landing (per OMRSD V09AJ0.095). Twenty-one minutes after wheel stop, the Orbiter nose cap RCC was 140 degrees F, the RH wing leading edge RCC panel #9 was 77 degrees F, and the RH wing leading edge RCC panel #17 was 77 degrees F (Figure 15).

Runway 33 was inspected and swept by KSC EG&G SLF personnel on 1 April 1992 and potentially damaging debris was removed.

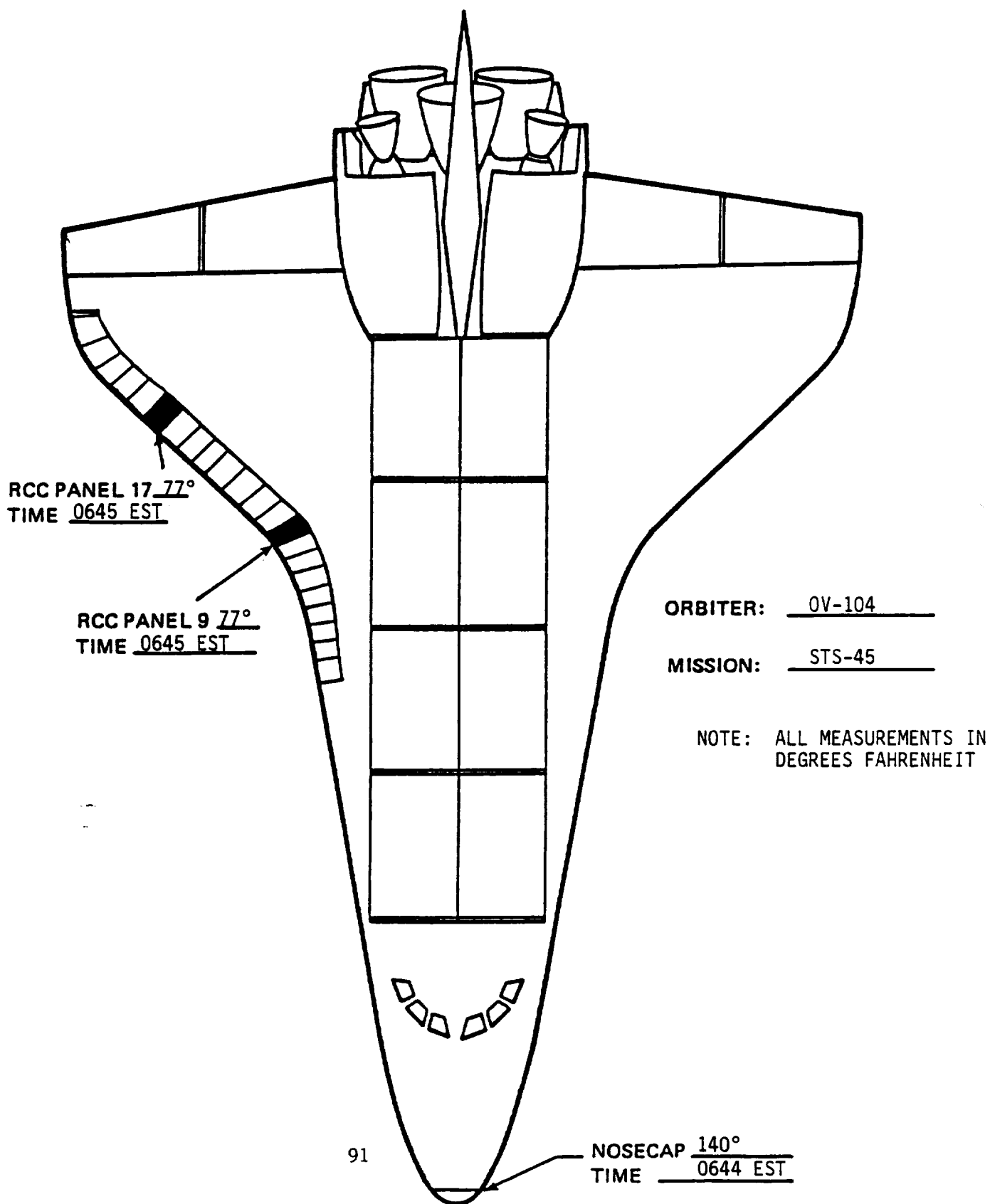
STS-45

FIGURE 14. CHEMICAL SAMPLE LOCATIONS



STS-45

FIGURE 15. TEMPERATURE MEASUREMENTS



A post-landing inspection of runway 33 was performed immediately after landing. The only flight hardware found was a white plastic parts tag from one of the nose landing gear tire pressure transducer separation harnesses.

In summary, the total number of Orbiter TPS debris hits was greater than average and the number of hits with a major dimension one inch or greater was near average when compared to previous flights (Figures 16-18).

Orbiter Post Launch Anomalies are listed in Section 10.

FIGURE 16: ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
AVERAGE	15.3	87.1	22.4	118.7
SIGMA	7.3	44.7	10.9	54.9
STS-45	18	122	22	172

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

COMPARISON TABLE

FIGURE 17.

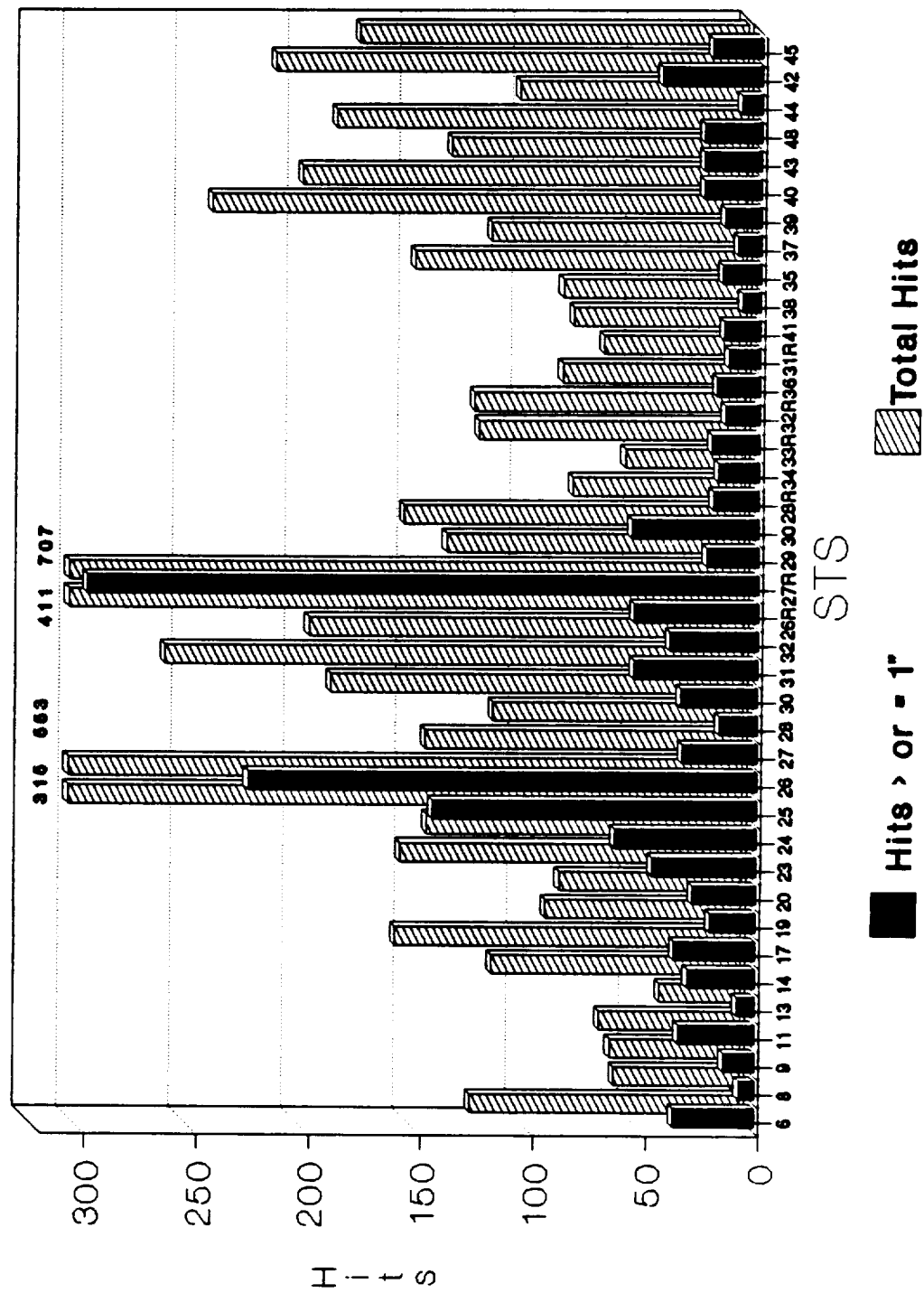
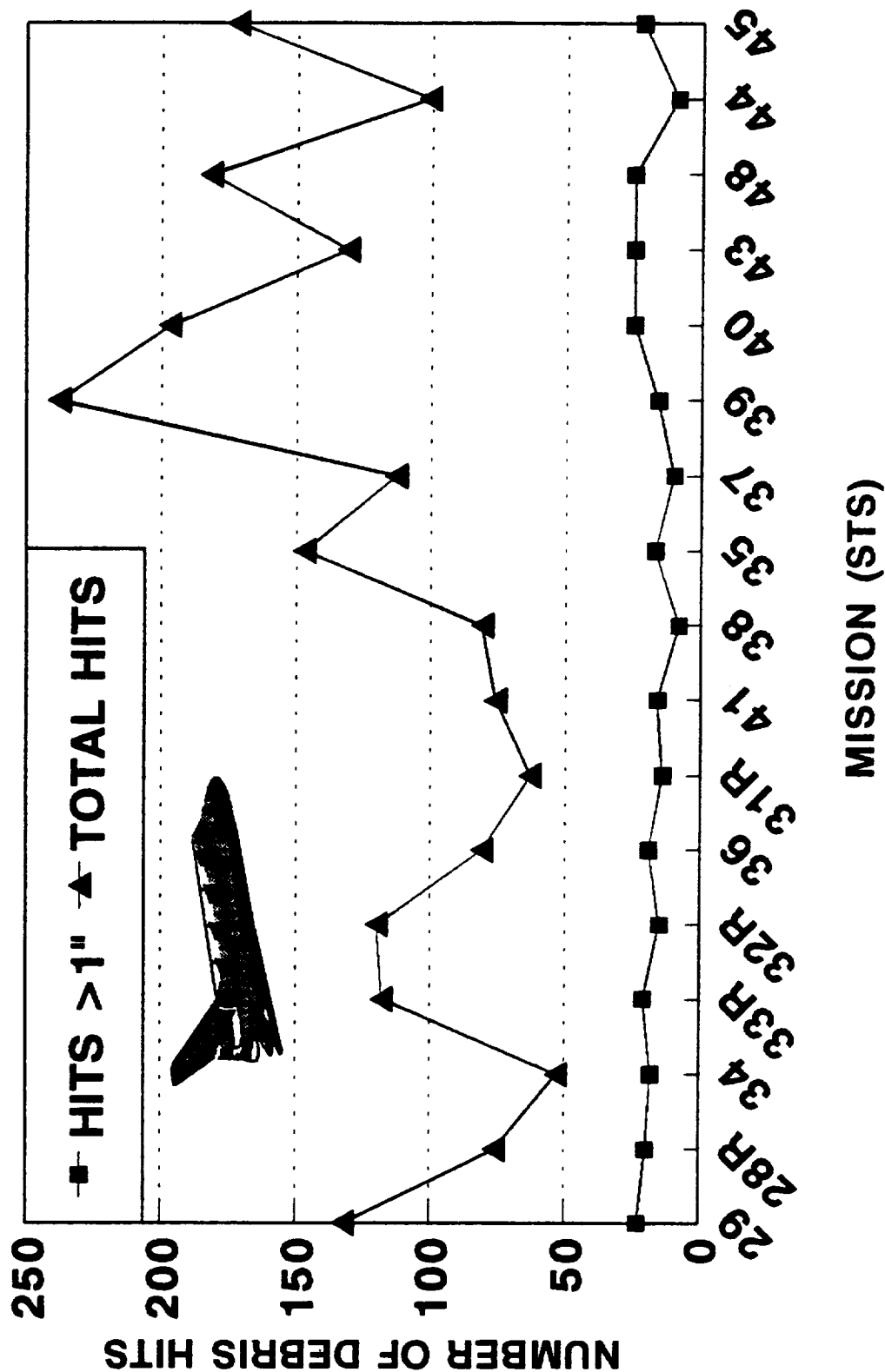
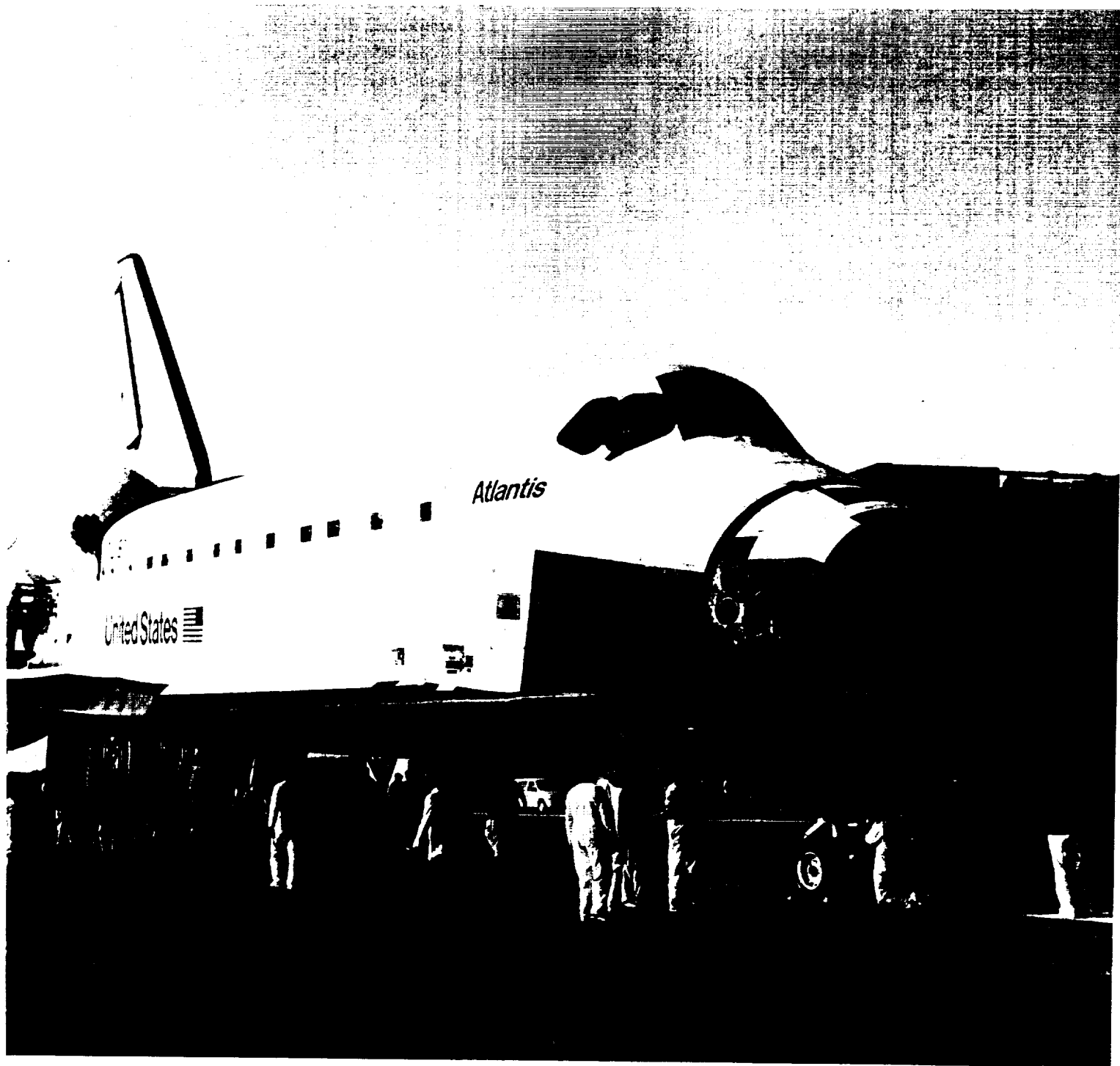


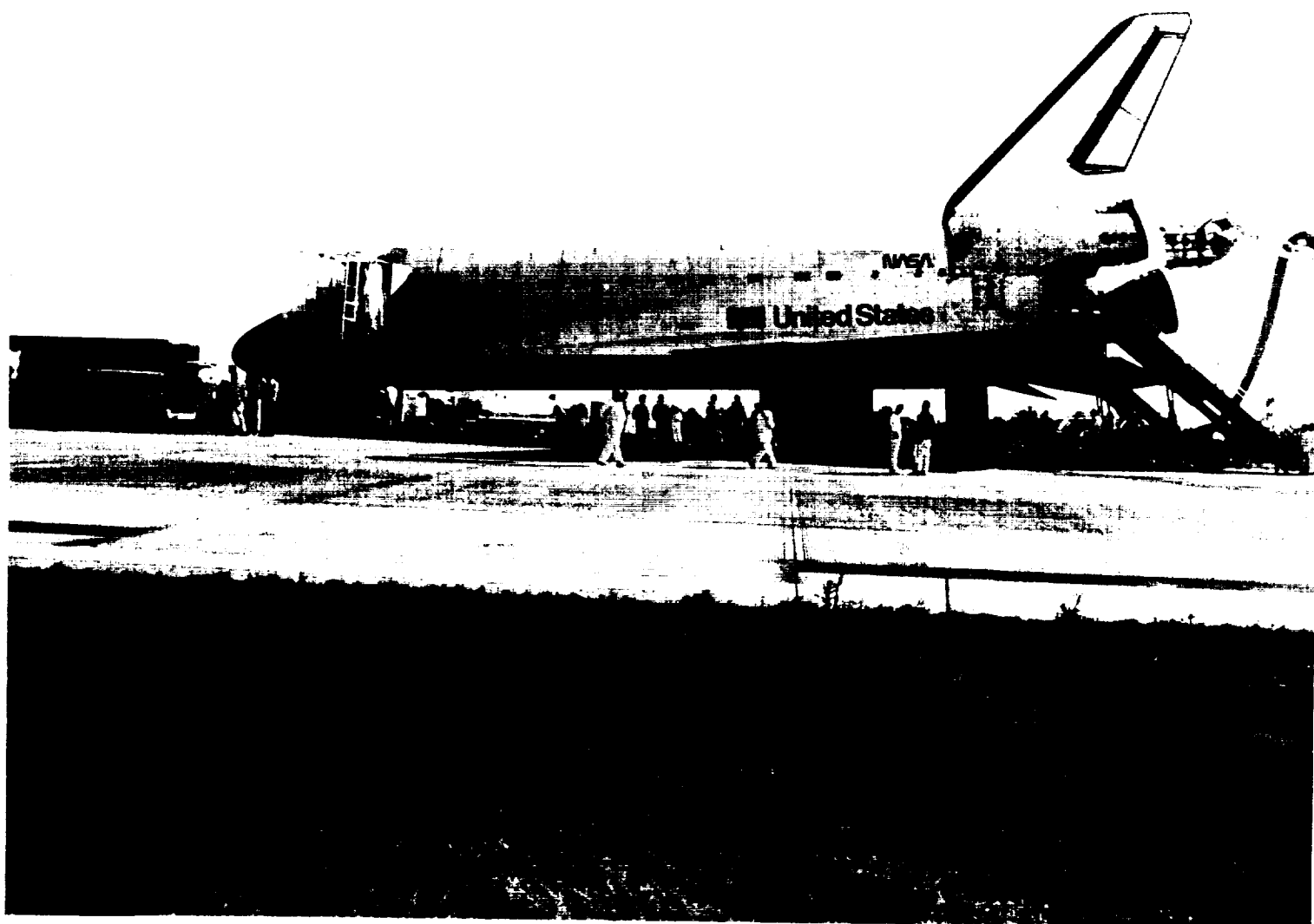
FIGURE 18

ORBITER TPS DEBRIS DAMAGE STS-29 THROUGH STS-45

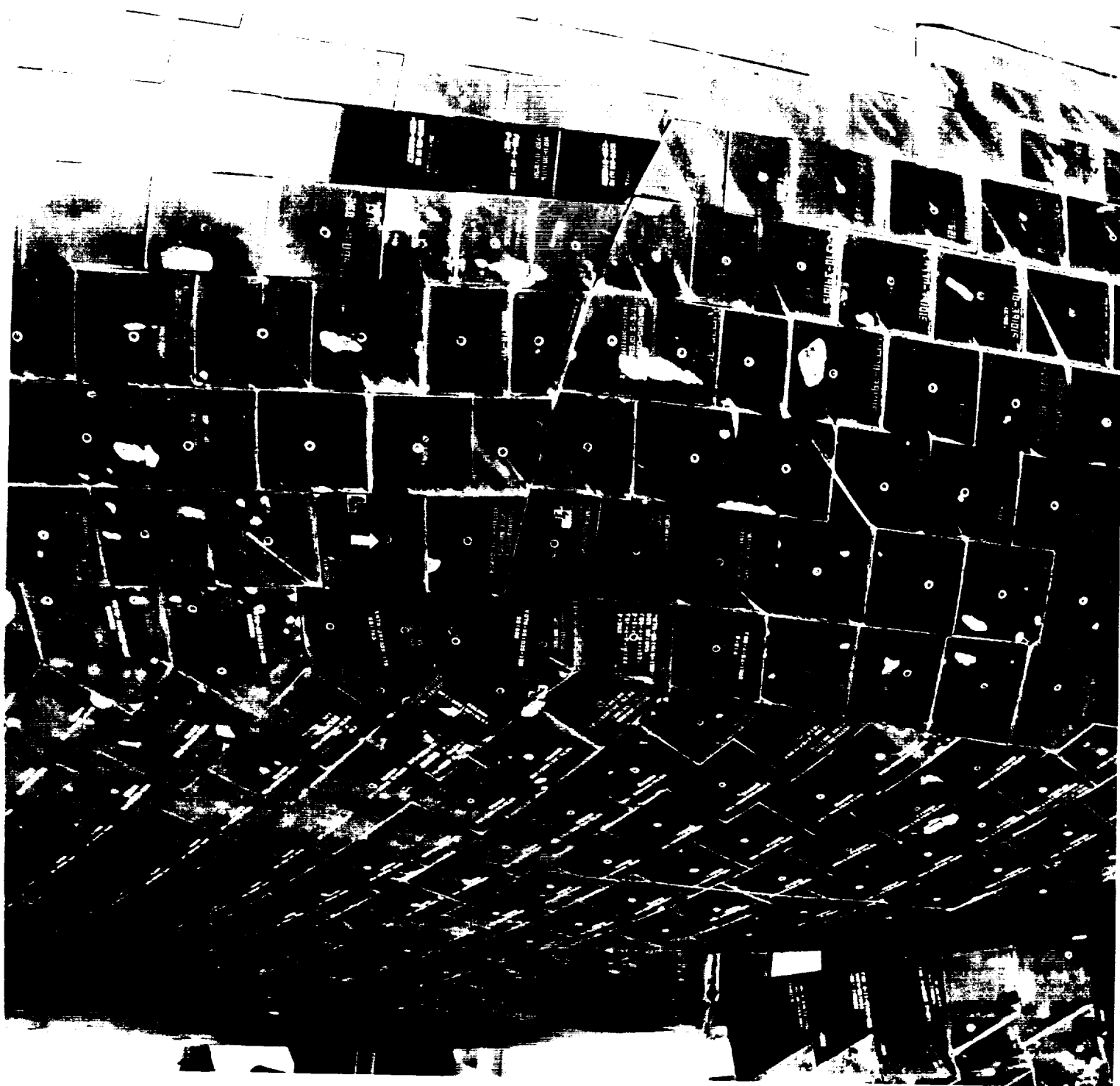




Overall view of Orbiter left side



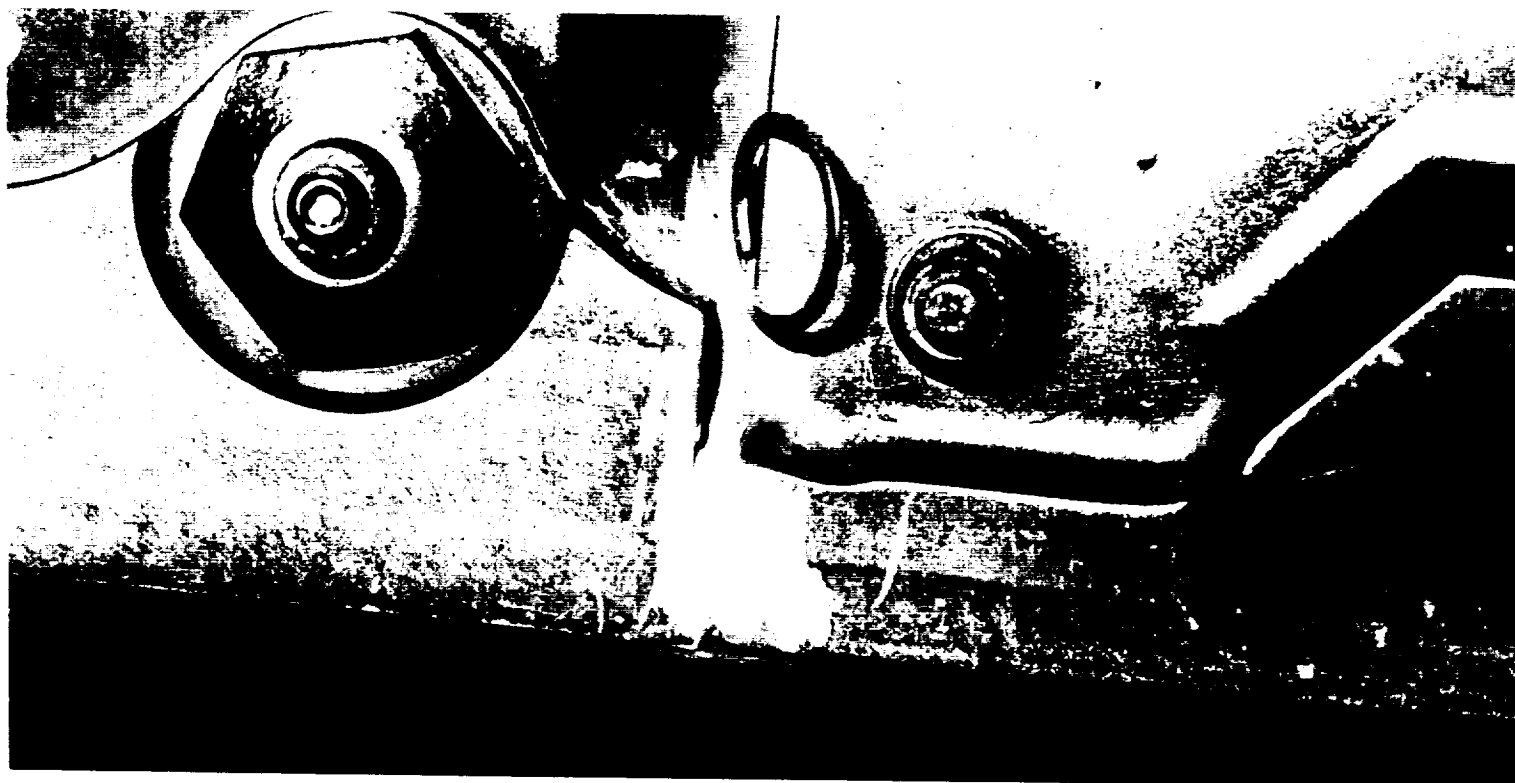
Overall view of Orbiter right side



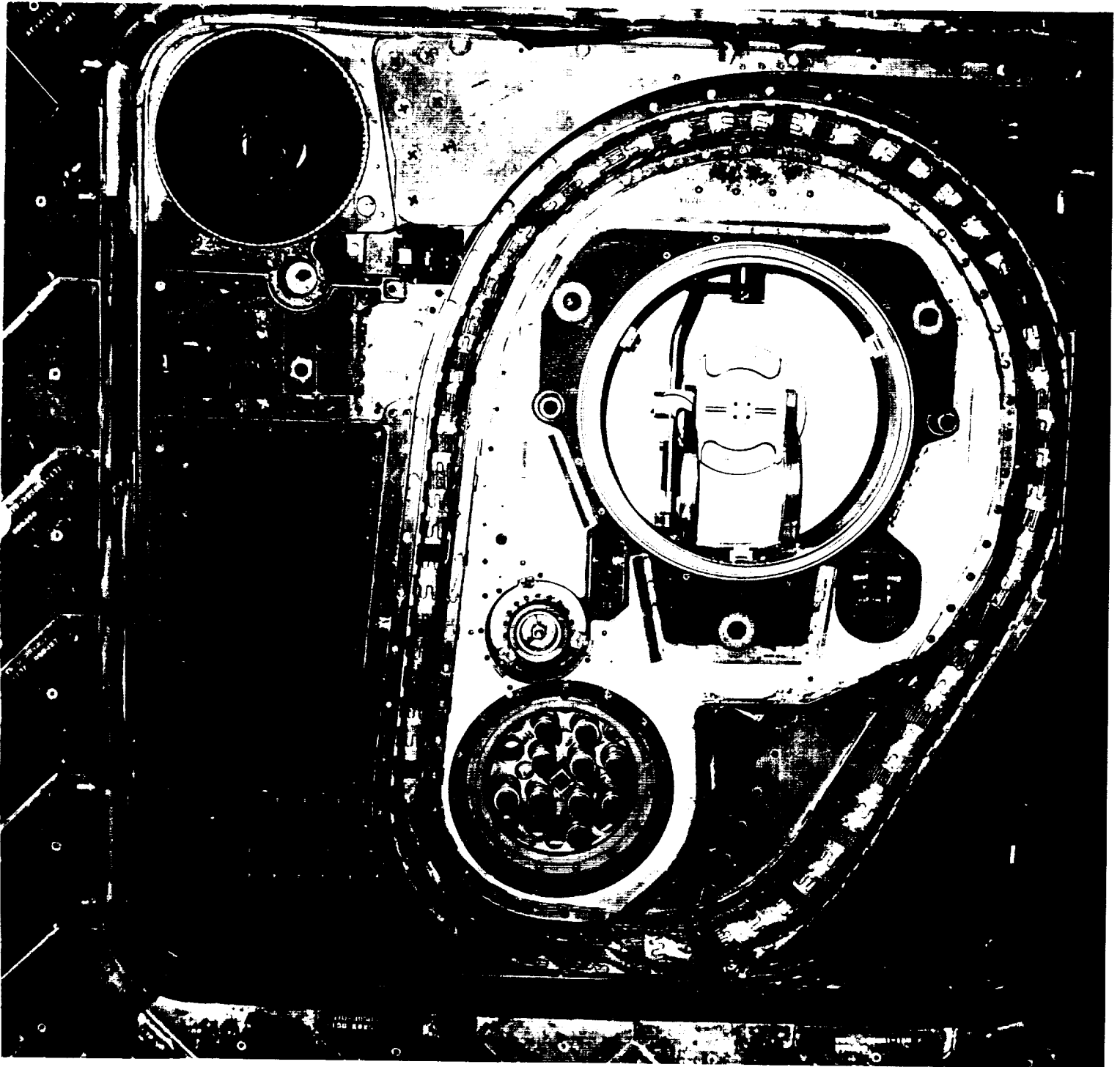
Thirty-seven hits, of which seven had a major dimension of one inch or greater, were located along the forward one-quarter of the lower right surface. Some of the hits may have been caused by ice from the ET L02 feedline upper bellows and support brackets.



One tile damage site contained an embedded debris particle. Lab analysis showed the particle (arrow) was composed of paint and an iron-rich material of unknown origin.



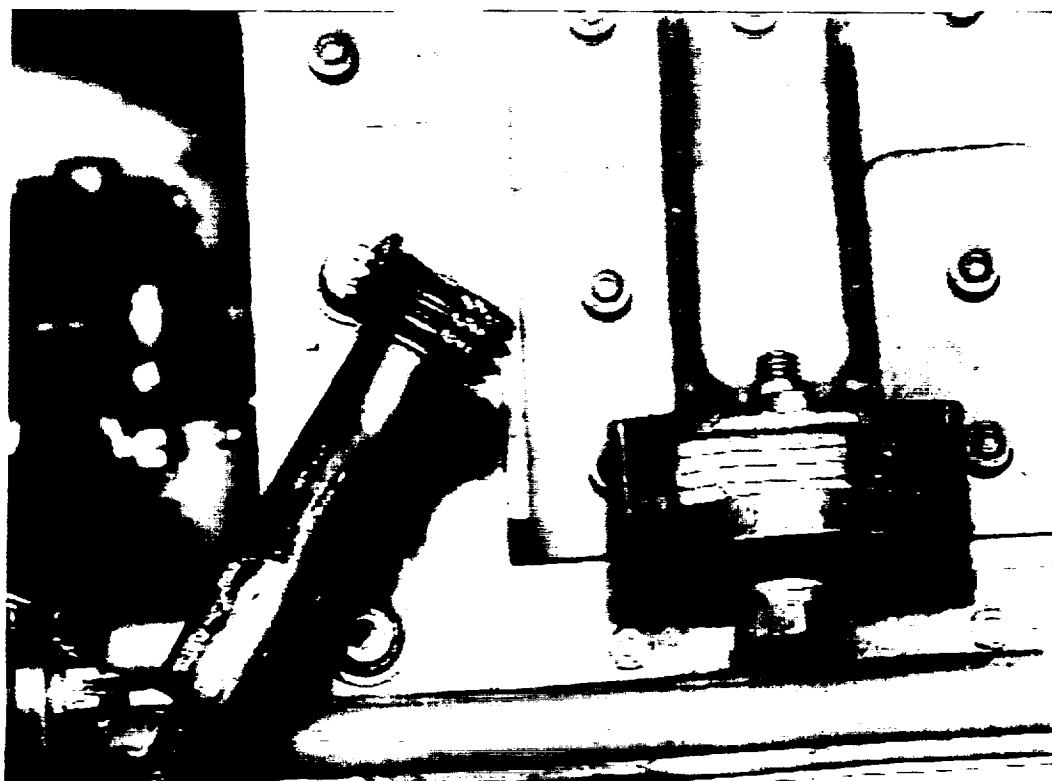
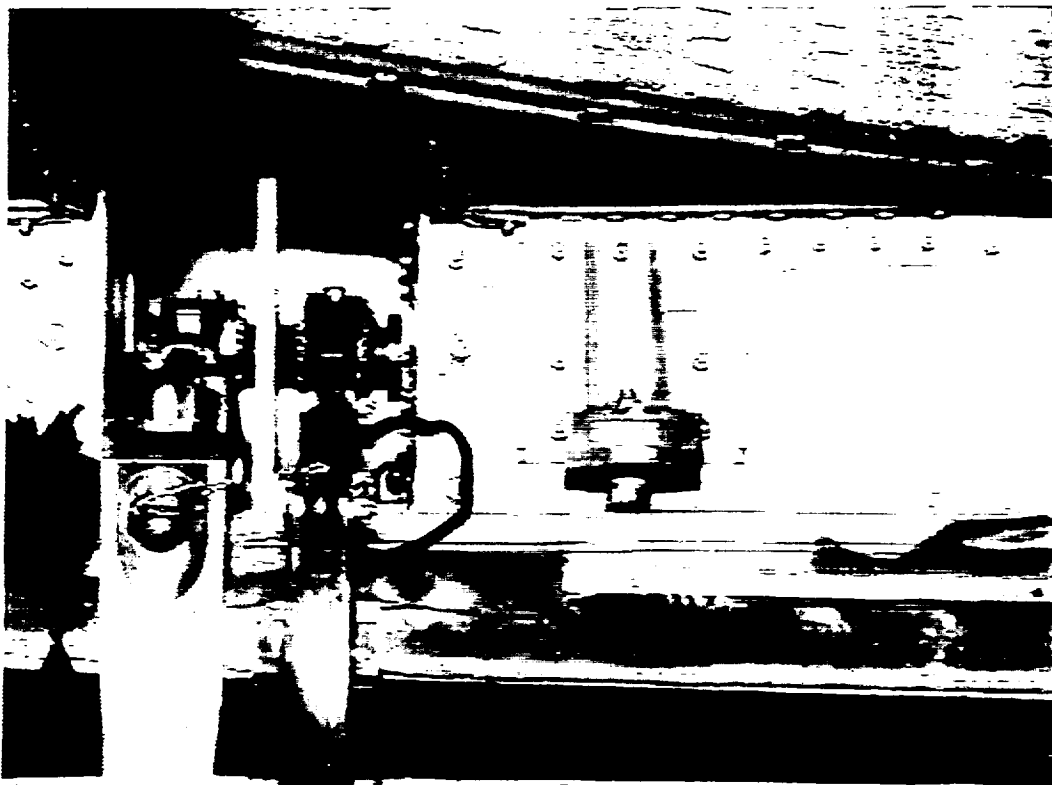
An expended NSI detonator from the aft umbilical separation system fell to the runway when the RH (LO2) ET umbilical door was opened. A coupler retaining ring from the same detonator was found adhering to some RTV on the inner surface of the door



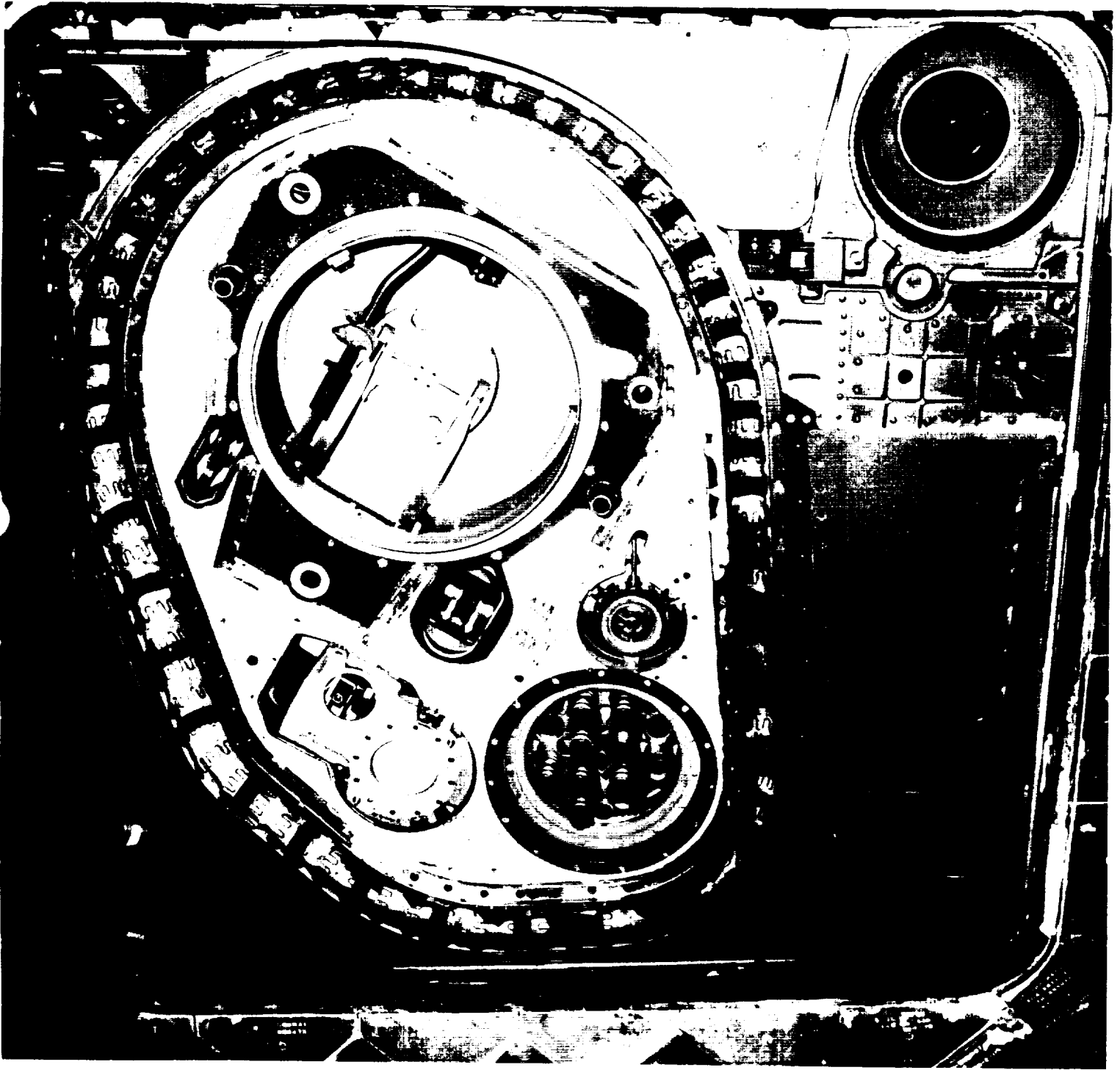
Overall view of the L02 ET/ORB umbilical



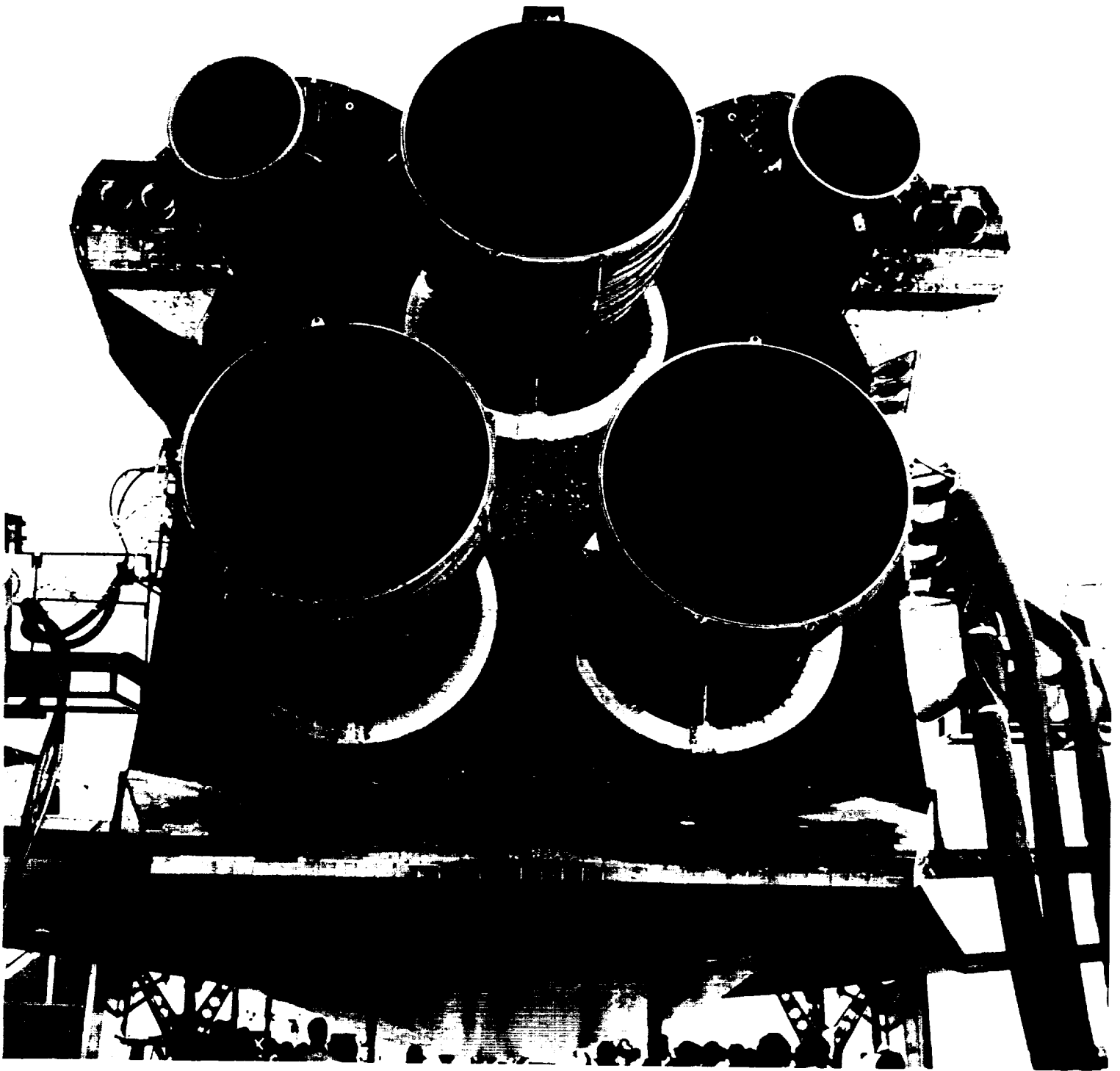
The separation ordnance device debris plunger in EO-3 was obstructed by a detonator booster and frangible nut half.



Because of the obstruction of the EO-3 plunger, a detonator booster from the separation system was allowed to escape and was found in the ET door hinge cavity.



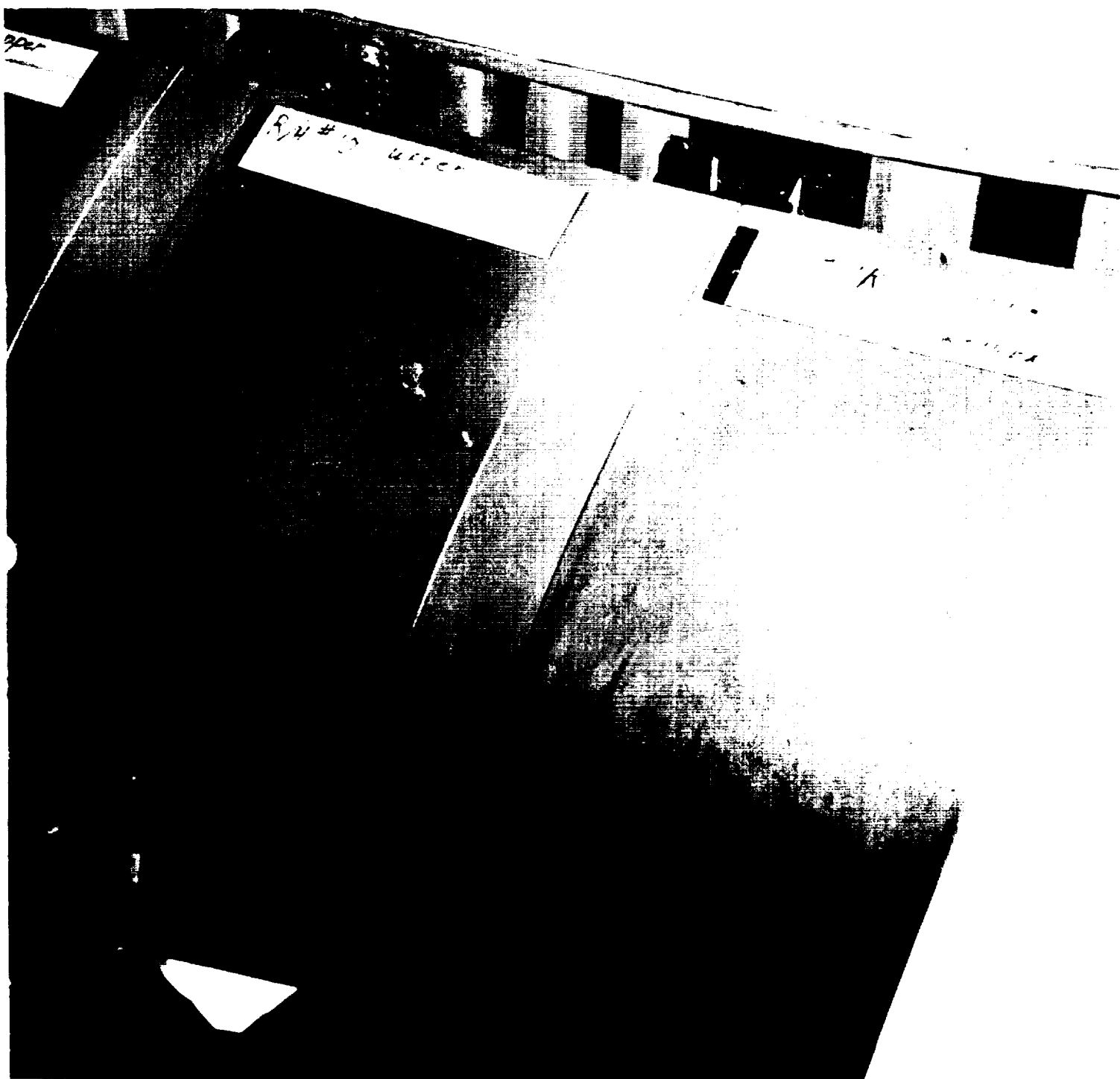
Overall view of the LH2 ET/ORB umbilical.



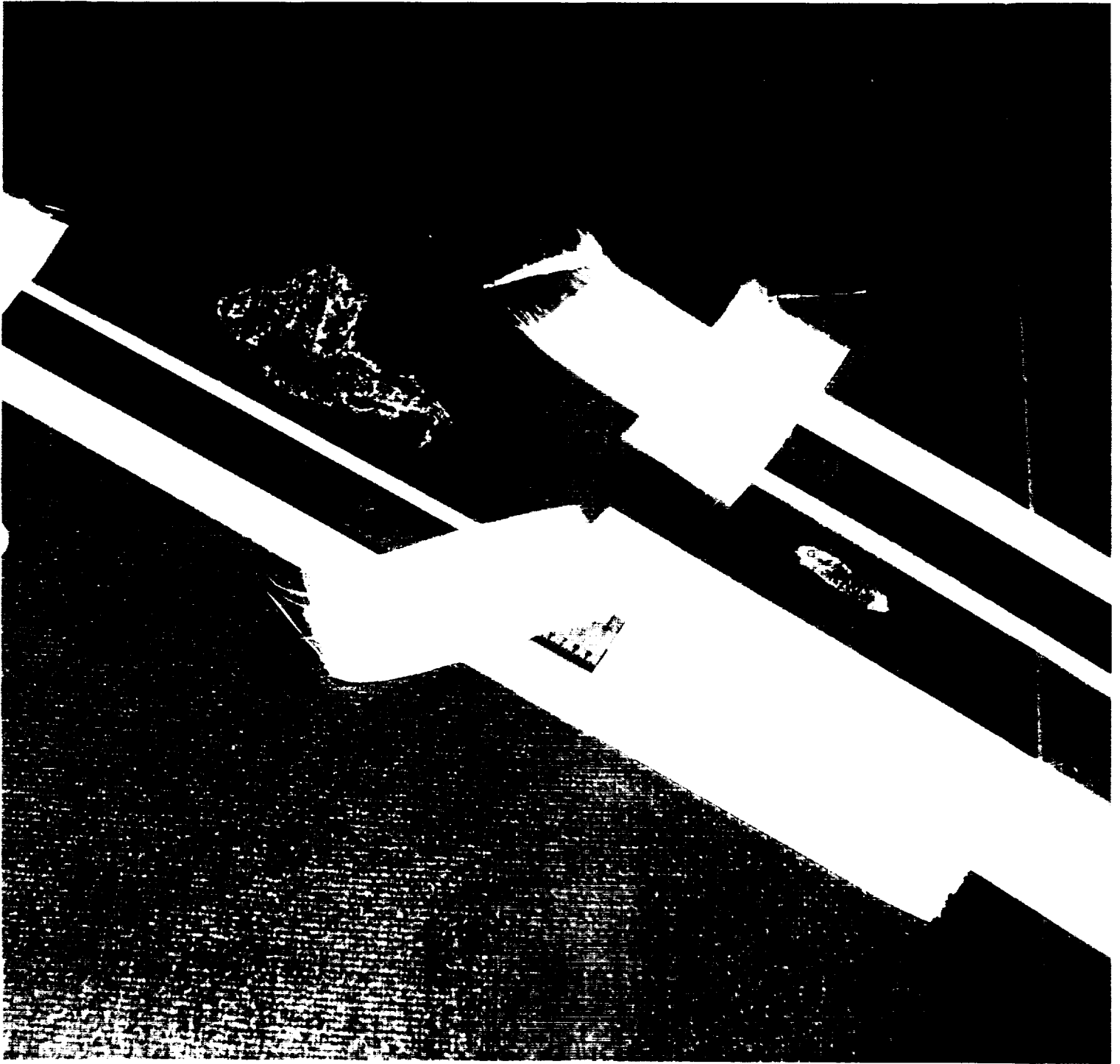
Damage to the base heat shield tiles was less than average. The closeout blanket on SSME #3 was badly torn and frayed from 7:30 to 12:00.



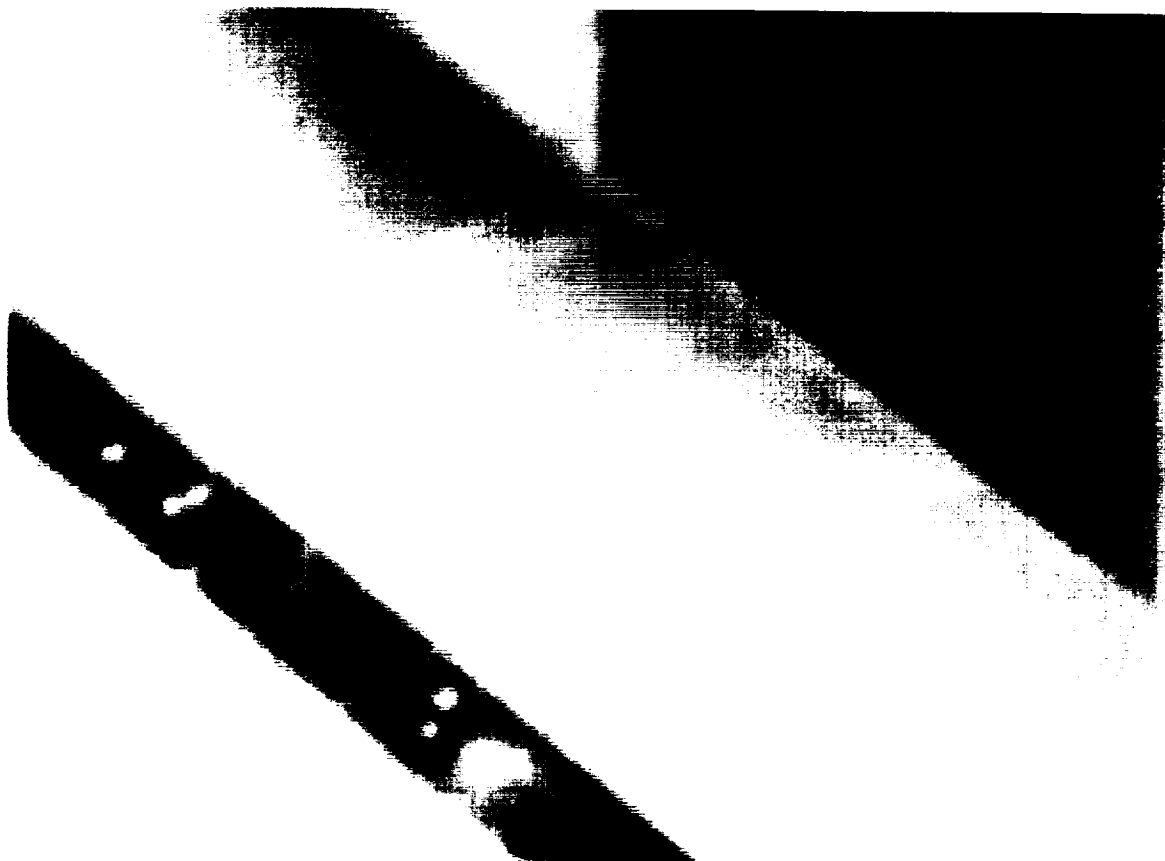
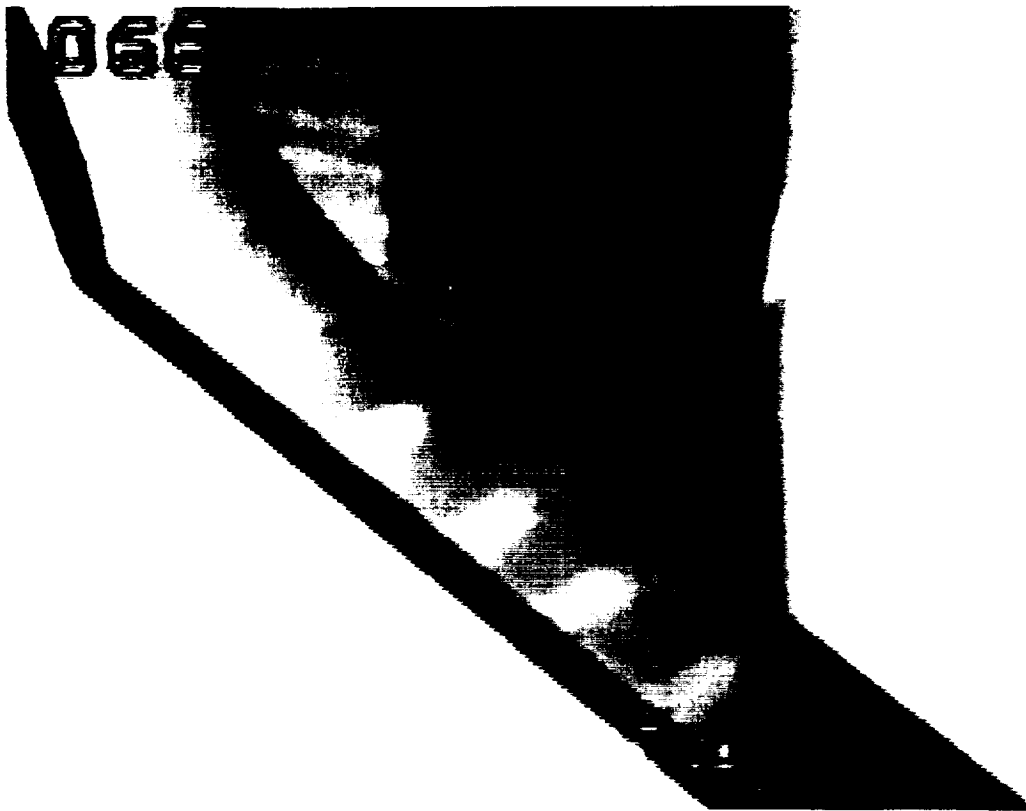
Three of the SSME Dome Mounted Heat Shield (DMHS) sacrificial patches were missing. Two of these missing patches were recovered near Pad A during the post launch debris inspection.



Two impact damage sites were present on the upper surface of the RH wing leading edge RCC panel #10



Laboratory analysis was unable to conclusively define impact speed/direction and time of impact (i.e. ascent, on-orbit, etc)



Vehicle surveillance using television camera OTV-066 showed no visible damage to the RCC #10 panel at T-1 hour 41 minutes prior to launch



Orbiter windows #3 and #4 exhibited light hazing with
a few small streaks

9.0 DEBRIS SAMPLE LAB REPORTS

A total of 9 samples were obtained from Orbiter OV-104 during the STS-45 post landing debris assessment at Kennedy Space Center (KSC), Florida (Figure 14). The nine submitted samples consisted of 8 window wipes and 1 residual sample from a tile damage site. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves the placing and correlating of particles with respect to composition, thermal (mission) effects, and availability. Debris sample results and analyses are listed by Orbiter location in the following summaries.

Orbiter Windows

Results of the window sample analysis revealed the presence of the following materials:

1. Metallics
2. RTV, silica tile, glass fibers, insulation
3. Cerium-rich materials
4. Paints, dust, rust and salt
5. Organics
6. Earth compounds

Debris analysis provides the following correlations:

1. Metallic particles (brass, aluminum, stainless and carbon steel alloys) are common to SRB/BSM exhaust residue, but are not considered a debris concern in this quantity (micrometer) and have not generated a known debris effect.
2. RTV, silica tile, glass fibers, and insulation originate from Orbiter TPS (thermal protection system).
3. Cerium-rich materials originate from Orbiter window polishing compounds.
4. Paint is of flight hardware/facility/GSE origin; dust and salt are naturally-occurring landing site products; rust is an SRB BSM exhaust residue.
5. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method; results are pending. This detailed process is more difficult due to small sample quantity.
6. Earth compounds (calcite and alpha-quartz) originate from the landing site.

Orbiter Tile Damage Site

Results of the Orbiter tile damage site sample indicated the presence of the following materials:

1. Silica tile
2. Paint
3. Iron-Potassium-Silicon-Aluminum material
4. Iron-Calcium-Silicon material
5. Iron-rich material

Debris analysis provides the following correlations:

1. Dark dense and white fibrous silica tile materials originate from Orbiter TPS (thermal protection system).
2. Paint is of flight hardware/facility/GSE origin.
3. The origin of Iron-Potassium-Silicon-Aluminum material cannot be determined due to small quantity of sample.
4. The origin of Iron-Calcium-Silicon material cannot be determined due to small quantity of sample.
5. The origin of Iron-rich material cannot be determined due to small quantity of sample.

Conclusions

The STS-45 mission sustained Orbiter tile damage to a less than average degree. The chemical analysis results from post flight samples did not provide data that points to a single source of damaging debris.

Orbiter window samples provided evidence of SRB/BSM exhaust, Orbiter TPS, Orbiter window polishing compound, landing site products, organics, and paint.

The Orbiter tile damage site sample results provided indications of thermal protection system (TPS) materials, paint, and Iron-rich materials that could not be positively identified due to the small sample size. The lack of sufficient sample for positive identification of the Iron-rich material prohibits conclusively establishing a possible debris source.

Future reports will include debris sample results in tabular form for use in debris source identification by repeatability of residual results (increase data populous). Even though this mission did not exhibit evidence of a debris concern, the change in format of analytical data should provide for an increased sensitivity to trends.

10.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 11 Post Launch Anomalies, including one IFA candidate, were observed on the STS-45 mission.

10.1 LAUNCH PAD/FACILITY

1. An OIS box and an 8"x14" metal panel lay in the south flame trench near the flame diverter. The OIS hardware originated from station 1-17 on the south side of the MLP (near the LH2 skid beneath the overhang). The attach hardware had failed due to corrosion causing the OIS box to shake loose from the launch vibration as the vehicle cleared the tower. Pad Operations will inspect the pad OIS boxes for similar problems. Film analysis confirmed the OIS box had not impacted the Orbiter right wing leading edge RCC panel #10 during liftoff.

10.2 EXTERNAL TANK

1. Flight crew observations and on-orbit photographs showed a conical shaped feature that may be indicative of residual hydrogen venting from the LH2 ET/ORB umbilical and appeared to originate from the 4-inch recirculation line interface area. Venting was also visible near the ET intertank and appeared to originate from the GUCP area. This is a Fluids issue rather than a Debris concern.

2. The only confirmed anomaly in the intertank area consisted of 10 TPS divots (4 on the -Y side, 6 on the +Y side) in the LH2 tank-to-intertank flange closeout. Loss of TPS from this area has contributed to tile damage on the lower surface of the Orbiter on previous flights.

10.3 SOLID ROCKET BOOSTERS

1. All south HDP EPON shim material was intact, but significantly debonded. The HDP #6 sidewall and bottom plate EPON shim material was completely debonded.

2. Two ordnance fragments fell from the HDP #7 DCS/stud hole shortly after liftoff (film item E-16). The HDP #7 Debris Containment System (DCS) plunger had not seated and was obstructed by a frangible nut half. Three small particles fell from the holddown post #5 DCS/stud hole area shortly after liftoff.

3. A stud hang-up occurred on HDP #4. The EPON shim bottom and sidewall material was pulled loose by the stud (film item E-7). Post flight inspection of the recovered SRB's showed broaching in the stud hole.

4. The Hypalon paint on the RH frustum was severely blistered and peeling the full circumference of the 395 ring frame and around the BSM's. Layers of MTA adhered to the peeled Hypalon paint.

10.4 ORBITER

1. Two pieces of SSME closeout blanket sacrificial patch material, each measuring 11"x16", were found southwest of the pad apron during the post launch pad inspections. Film analysis showed a section of SSME closeout blanket sacrificial patch material originated at SSME #3, fell aft near SSME #1, and separated into two pieces in the SSME plume. Post landing inspection of OV-104 revealed three pieces of sacrificial patch material were missing from SSME #3 and one from SSME #2.

2. The EO-3 debris plunger was obstructed by a frangible nut half and a detonator booster. A detonator booster from the EO-3 separation system was found in the ET door hinge cavity.

3. An expended NASA Standard Initiator (NSI) with an attached connector coupling ring from the aft umbilical separation system fell to the runway when the RH (LO2) ET umbilical door was opened. A coupler retaining ring from the same detonator was found adhering to some RTV on the inner surface of the RH ET door.

4. Two impact damage sites were present on the upper surface of the right wing RCC panel #10 (IFA candidate).

Appendix A. JSC Photographic Analysis Summary

Space Shuttle

Photographic and Television
Analysis Project

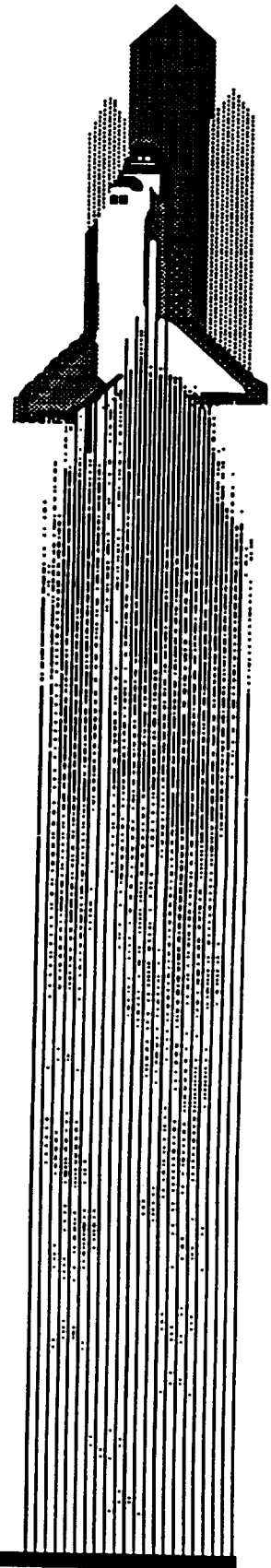
STS-45 Final Report

May 11, 1992



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058



2.0 Summary of Significant Events Analysis

2.1 Debris

2.1.1 Debris near the Time of SSME Ignition

2.1.1.1 LH2 and LO2 Umbilical Disconnect Debris

(Cameras E-005, E-006, E-019, E-020, E-025, E-026, E-031, E-040, E-052, E-076, OTV-009, OTV-054, OTV-063)

Normal ice debris was noted falling from both the LH2 and LO2 umbilical disconnect areas at SSME ignition through liftoff. There was less ice falling from the umbilical areas than has been seen on previous missions. None of the debris appeared to strike the vehicle.

2.1.1.2 Rope-like Debris from Right RCS R4D

(Cameras E-002, E-003, E-015, E-017)

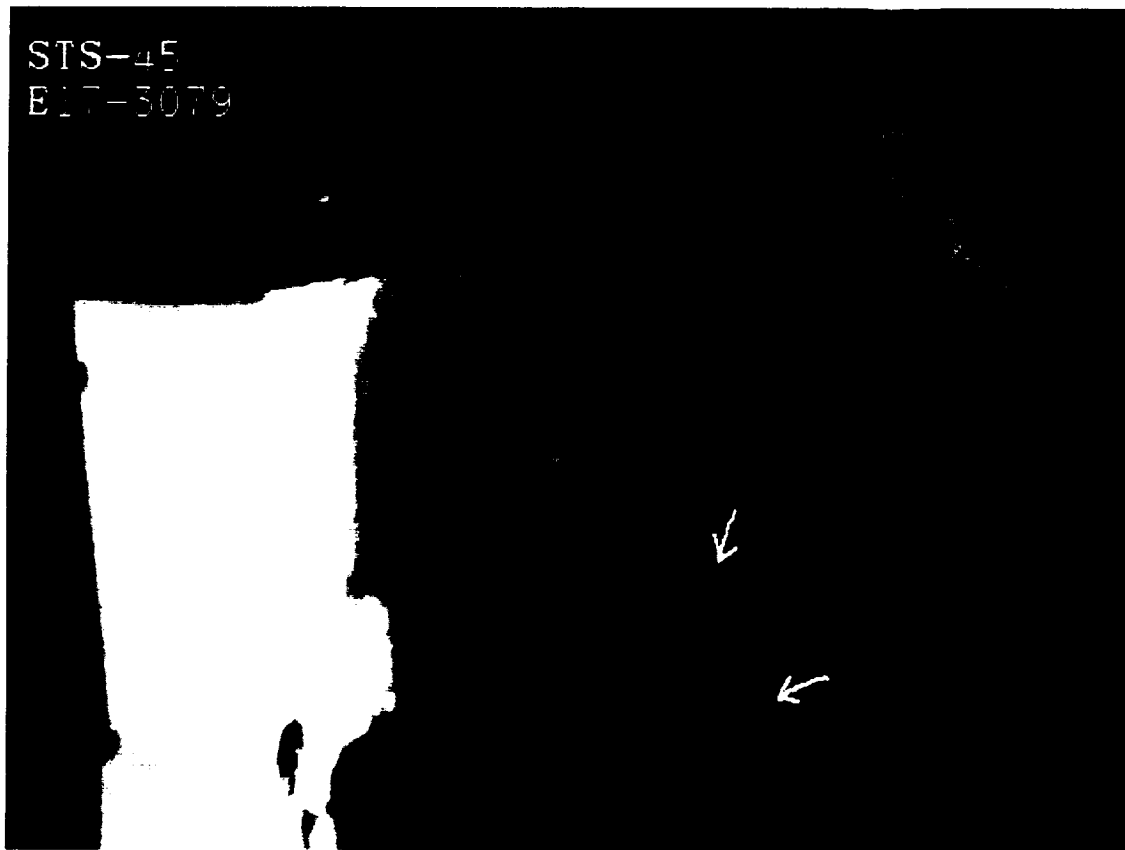


Figure 2.1.1.2 Rope-like Debris Seen near Port RCS at Liftoff

A single, thin rope-like piece of dark debris originated from behind the right RCS (port) stinger and fell aft at liftoff. The debris was identified by KSC to be a bead of RTV adhesive used to bond the RCS paper cover to the thruster at R4D. KSC reported that this event has been seen before. No follow-up analysis has been requested.

2.0 Summary of Significant Events Analysis

2.1.2 Debris near the Time of SRB Ignition

2.1.2.1 SRB Flame Duct Debris (Task #7) *(Cameras EX-001, E-001, E-007, E-008, E-010, E-011, E-013, E-015, E-025, E-027 and E-028, OTV-054)*

As on previous missions, several pieces of debris were noted originating from the SRB flame ducts near the holddown posts during and after SRB ignition.

On camera E-014, a long rope-like piece of debris was seen near the LSRB HDP M-8 at liftoff. This appeared to be excess rope used to tie down the water baffles at the flame duct.

On camera E-026, a flat piece of dark debris first seen north of the SRBs, traveled south past the LSRB and under the left wing during liftoff. See Figure 2.1.2.1.

On camera E-025, multiple small pieces of white debris (possibly from flame duct) traveled from the aft end of the ET/SRB area toward the LO2 TSM at liftoff.

Several small, light-colored pieces of debris fell aft along the right side of the ET at liftoff as seen on camera OTV-054.

Velocity measurements were made on two fast-moving pieces of debris that traveled from the LSRB flame duct toward the RSRB. The trajectory of these pieces were digitized on a Film Motion Analyzer. One of these particles was seen to exit the flame duct area just after SRB ignition and the other was observed as the SRB cleared the MLP. The maximum velocity of these particles was calculated to be 89 feet per second.

None of the observed debris appeared to strike the orbiter.

Plots of velocity versus time are located in Appendix D Task #7.

Several films were reviewed to determine if individual pieces of debris could be seen by more than one camera. If this were true, a phototheodolite solution of the trajectory of the debris could then be calculated. However, none of the observed flame duct debris satisfied the restrictions of the phototheodolite solution. No follow-up action has been requested.

2.0 Summary of Significant Events Analysis

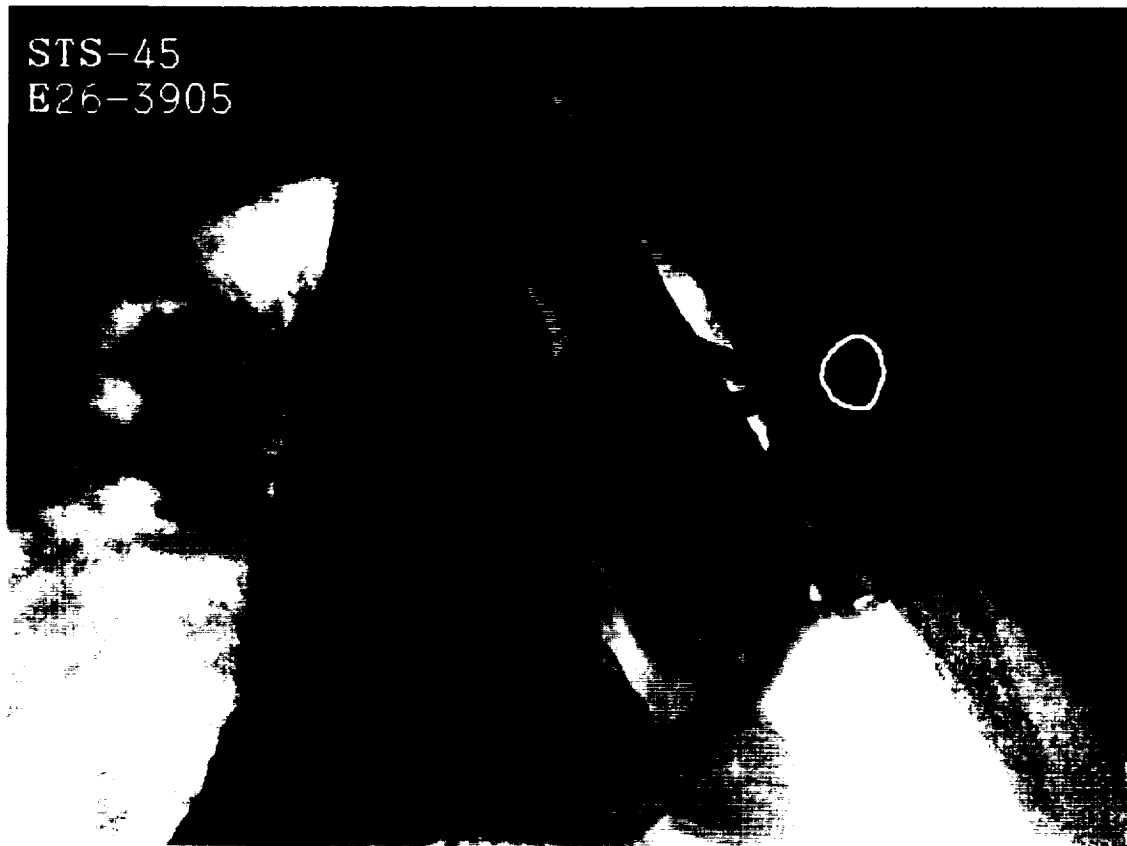


Figure 2.1.2.1 Debris Seen at Base of SRBs During Liftoff

On camera E-026, a shiny, flat piece of debris appeared at the base of the SRBs and moved south under the left inboard elevon during liftoff. The debris did not appear to strike the vehicle. No follow-up action has been requested.

2.0 Summary of Significant Events Analysis

2.1.2.2 Debris from SRB HDPs M-5, M-7, M-8 (Cameras E-007, E-011, E-014, E-016, E-028 and EX-004)

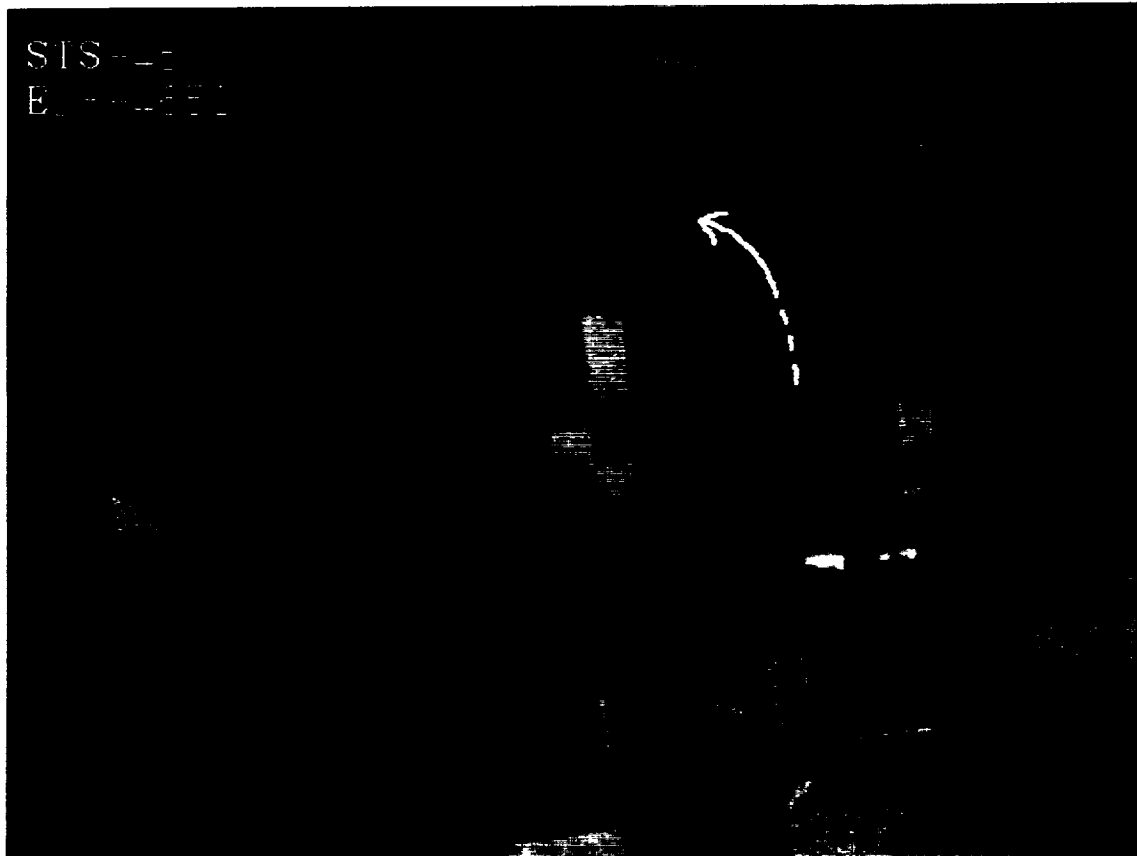


Figure 2.1.2.2 Dark Debris from LSRB Stud Hole at HDP M-7

A single piece of dark debris originated from the LSRB stud hole at HDP M-7 and fell after liftoff. See Figure 2.1.2.2. The debris was estimated to be 3 x 0.5 inches in size. This event was seen on cameras E-016, E-011 and E-028.

On camera EX-004, several small pieces of dark debris appeared to originate from the LSRB HDP M-5 area after PIC firing as the foot lifted off the holddown post shoe.

None of the above debris appeared to strike the vehicle. No follow up analysis of the debris seen near the holddown posts has been requested.

2.0 Summary of Significant Events Analysis

2.1.2.3 Epon Shim Material from RSRB Aft Skirt Foot at HDP M-4 during Liftoff (Cameras E-007, E-011, E-014, E-016, E-028 and EX-004)

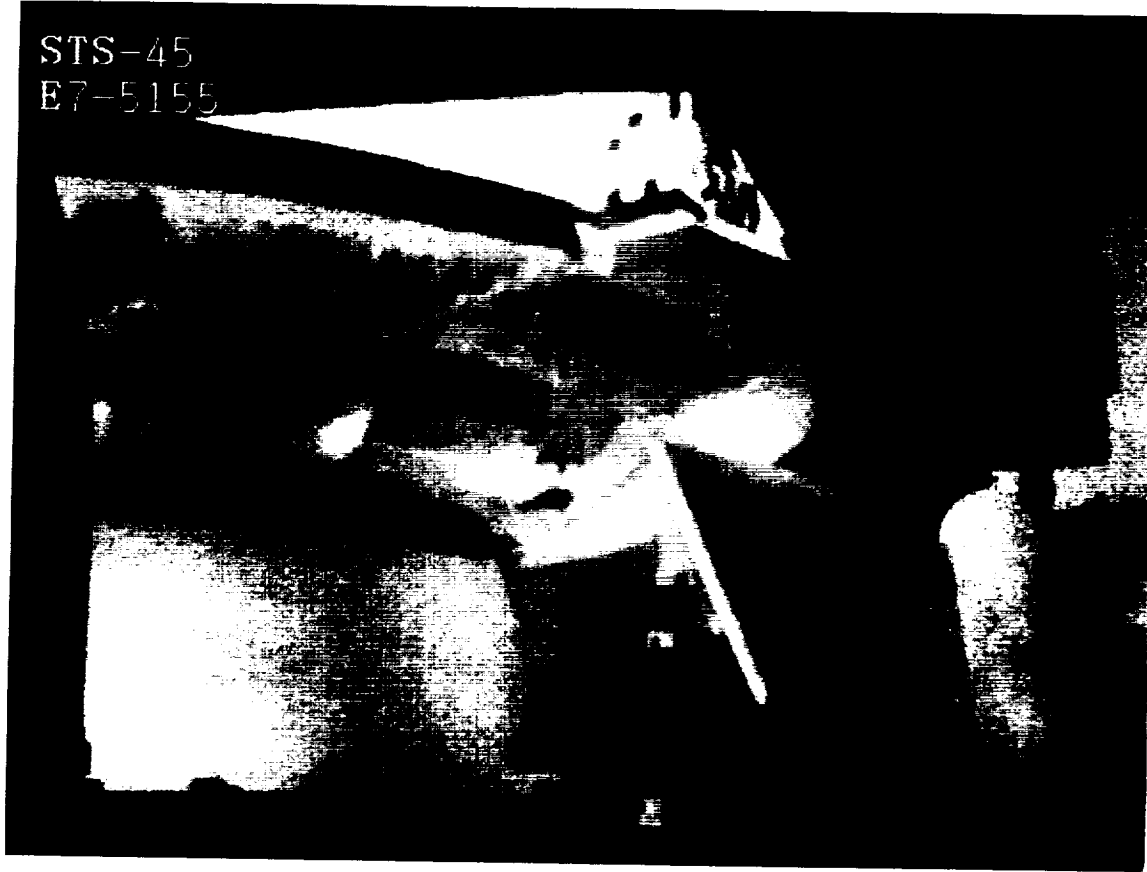


Figure 2.1.2.3 Epon Shim Material from RSRB Aft Skirt Foot at Liftoff

On camera E-007, epon shim material detached from the RSRB aft skirt foot at HDP M-4 and fell into the flame duct at liftoff. See Figure 2.1.2.3. Loose shim material was previously seen on STS-38 at the same holddown post. No follow up analysis of this event has been requested.

2.0 Summary of Significant Events Analysis

2.1.3 Debris after Liftoff

Multiple pieces of debris were seen falling aft of the SLV from liftoff through ascent on the launch tracking views. Most of the debris sightings were probably RCS paper or ice from the ET/Orbiter umbilicals. The debris did not appear to strike the vehicle. No follow-up analysis has been requested.

2.1.3.1 SLV Debris at Tower Clear through Roll Maneuver (Cameras E-040, KTV-4A)

Several pieces of white debris were seen in the exhaust plume just after tower clear on camera E-040. On camera KTV-4A, a light-colored piece of debris, first seen near the base of the vertical stabilizer, fell aft of the vehicle just after roll maneuver. The debris did not appear to strike the vehicle. No follow-up analysis has been requested.

2.1.3.2 Orange Debris from near LO2 Umbilical at 23.7 seconds MET (Cameras E-212, E-213, E-222)

On cameras E-212, E-213 and E-222, a single piece of orange debris appeared to originate from the LO2 umbilical area. The debris became entrained in the recirculation flow and fell aft at 23.674 seconds.

2.0 Summary of Significant Events Analysis

2.1.3.3 White Debris near SSME #1 at 31.3 seconds MET (Camera E-212, E-213, E-222, ET-212 and OTV-054)



Figure 2.1.3.3 White Debris behind SSME #1 Fell Aft and Split into Two Pieces at 31.277 seconds MET

A single large piece of white debris, first noted behind SSME #1, fell aft and appeared to split into two pieces at approximately 31.277 seconds MET. See Figure 2.1.3.3. KSC believed that this debris was part of the closeout blanket patch material found near the pad after launch.

2.0 Summary of Significant Events Analysis

2.1.3.4 Orange Debris Aft of LSRB at 71 seconds MET (Camera E-212)



Figure 2.1.3.4 Orange Debris from Tail End of LSRB Fell Aft at 71 seconds MET

A single piece of orange debris originated near the tail end of the LSRB and fell aft at approximately 71 seconds MET.

None of the above-mentioned debris appeared to strike the vehicle. Debris falling aft of the SLV after liftoff has been seen on films and videos from previous missions. Most of this type of debris has been attributed to ice or RCS paper. No further analysis has been requested.

2.0 Summary of Significant Events Analysis

2.2 MLP Events

2.2.1 Uncovered RCS Nozzles *(Camera E-017)*

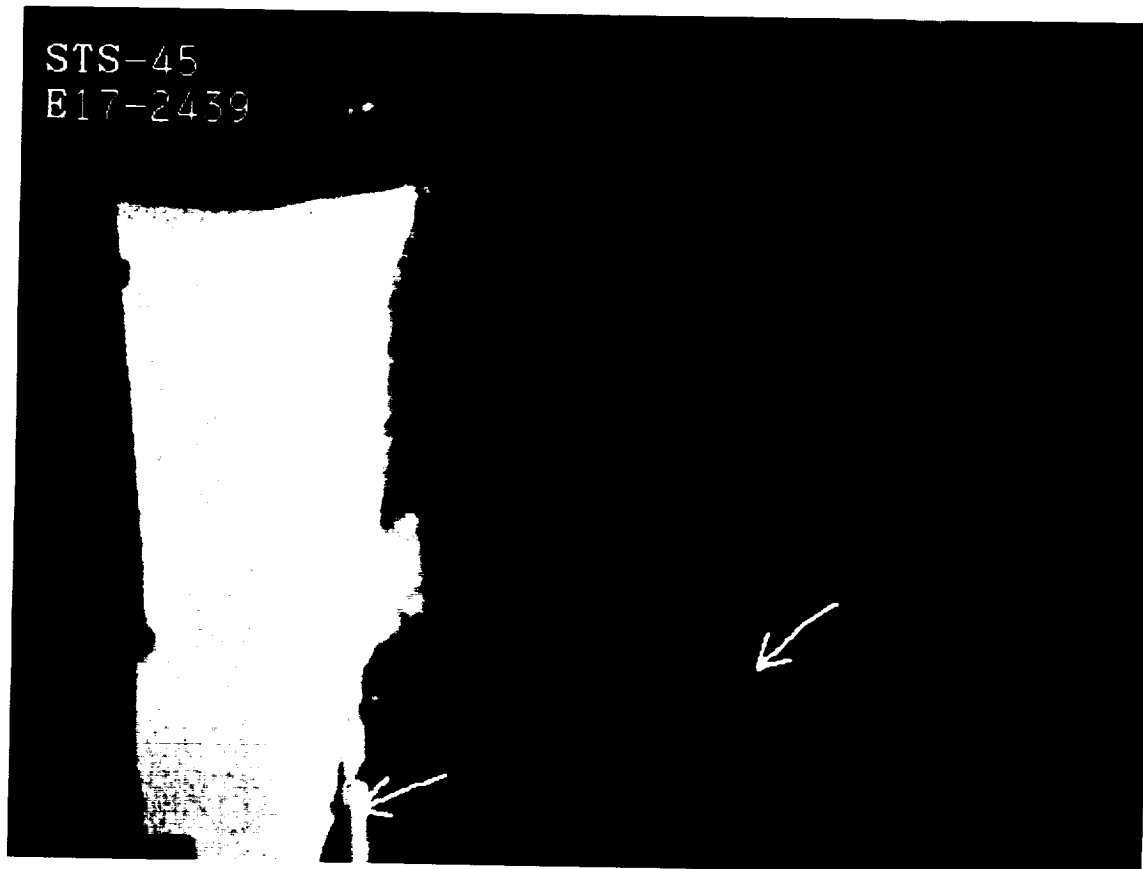


Figure 2.2.1 RCS Ports R3D and R3R were Uncovered Prior to SSME Startup

RCS ports R3D and R3R were not covered with butcher paper prior to the time of launch. KSC reported that the butcher paper fell off after the March 22 tanking attempt. A waiver from having to replace the paper was issued to KSC. No follow-up analysis has been requested.

2.0 Summary of Significant Events Analysis

2.2.2 Water Leak in MLP J-Pipes *(Camera E-010, E-011 and E-016)*

A continuous water leak was noted from different sections of the MLP J-pipes both prior to and after SSME ignition. A similar event was last seen on STS-37. No follow-up analysis has been requested.

2.2.3 Vapor at LH2 Umbilical Prior to SSME Ignition *(Camera OTV-009)*

On OTV-009, a slight vapor was noted at the top of the LH2 umbilical prior to ignition. A review of videos from earlier missions revealed that this event has occurred before. In fact, there appeared to be less vapor seen at the umbilicals on STS-45 than on some earlier missions. No follow-up analysis has been requested.

2.2.4 Base Heat Shield Erosion *(Cameras E-019 and E-020)*

On camera E-020, TPS erosion was seen at the base of the left OMS nozzle at SSME ignition. On camera E-019, slight base heat shield erosion was noted between SSMEs #1 and #3 at liftoff. Base heat shield erosion has been seen on films from most of the previous missions since reflight. No follow-up analysis has been requested.

2.0 Summary of Significant Events Analysis

2.2.5 RSRB HDP M-4 Bolt Hang-up (Camera E-007)

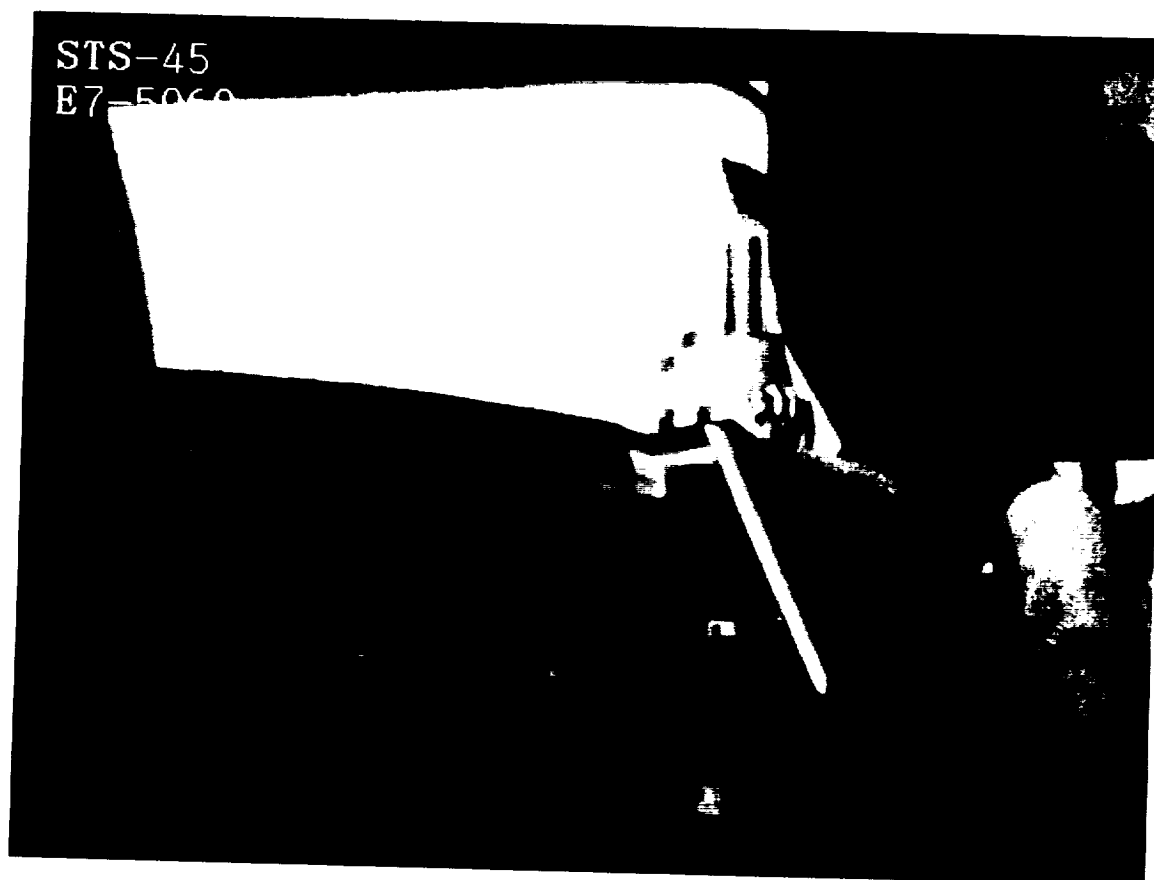


Figure 2.2.5 Bolt Hang-up at RSRB HDP M-4 During Liftoff

A bolt hang-up was noted at the RSRB HDP M-4. The bolt appeared to bend during liftoff until the aft skirt foot released it, causing the bolt to spring back to a vertical position. See Figure 2.2.5. A review of previous occurrences of bolt hang-ups since reflight was conducted. Note that earlier hang-ups have all been at different holddown posts.

MISSION	LOCATION OF HANG-UP
STS-34	RSRB holddown post M-2
STS-33	RSRB holddown post M-3
STS-39	RSRB holddown post M-1 (slight)
STS-43	LSRB holddown post M-7
STS-45	RSRB holddown post M-4

2.0 Summary of Significant Events Analysis

2.2.6 LSRB Firing Cable Remained Attached at Liftoff (Cameras E-013)

An HDP M-6 firing (PIC) cable remained attached to the LSRB during liftoff. This event was seen with a RSRB firing cable on STS-37 and two LSRB firing cables on STS-39. No follow-up analysis has been requested.

2.3 Ascent Events

2.3.1 White Flashes in SSME Plume after Roll Maneuver (Cameras E-052, E-054, E-057, E-213 and E-222)

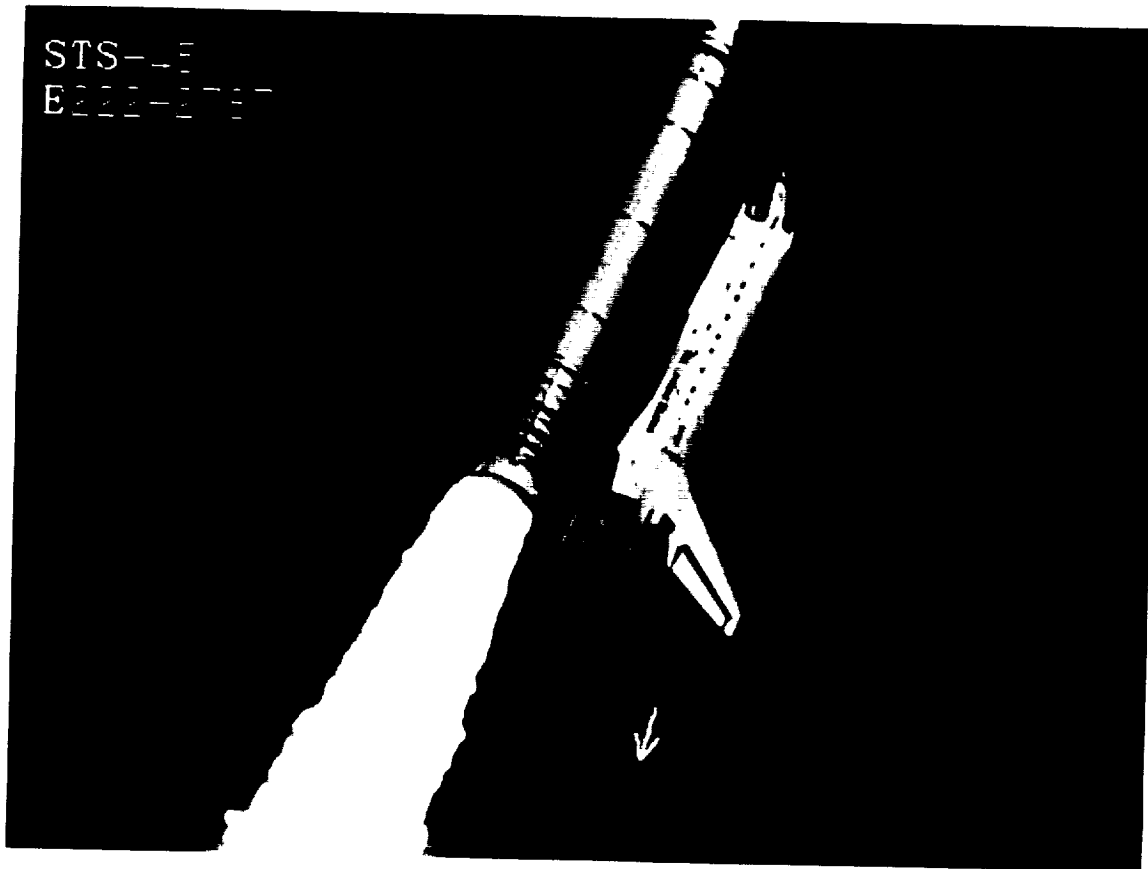


Figure 2.3.1 Flash in SSME Exhaust Plume just after Roll Maneuver

Several white flashes were visible in the SSME plume just after roll maneuver. These flashes were seen from approximately 15 seconds MET through about 27 seconds MET. This event has been noted on previous missions during this time frame. No follow up analysis has been requested.

2.0 Summary of Significant Events Analysis

2.3.2 Flares in SSME Plume (Camera E-222)

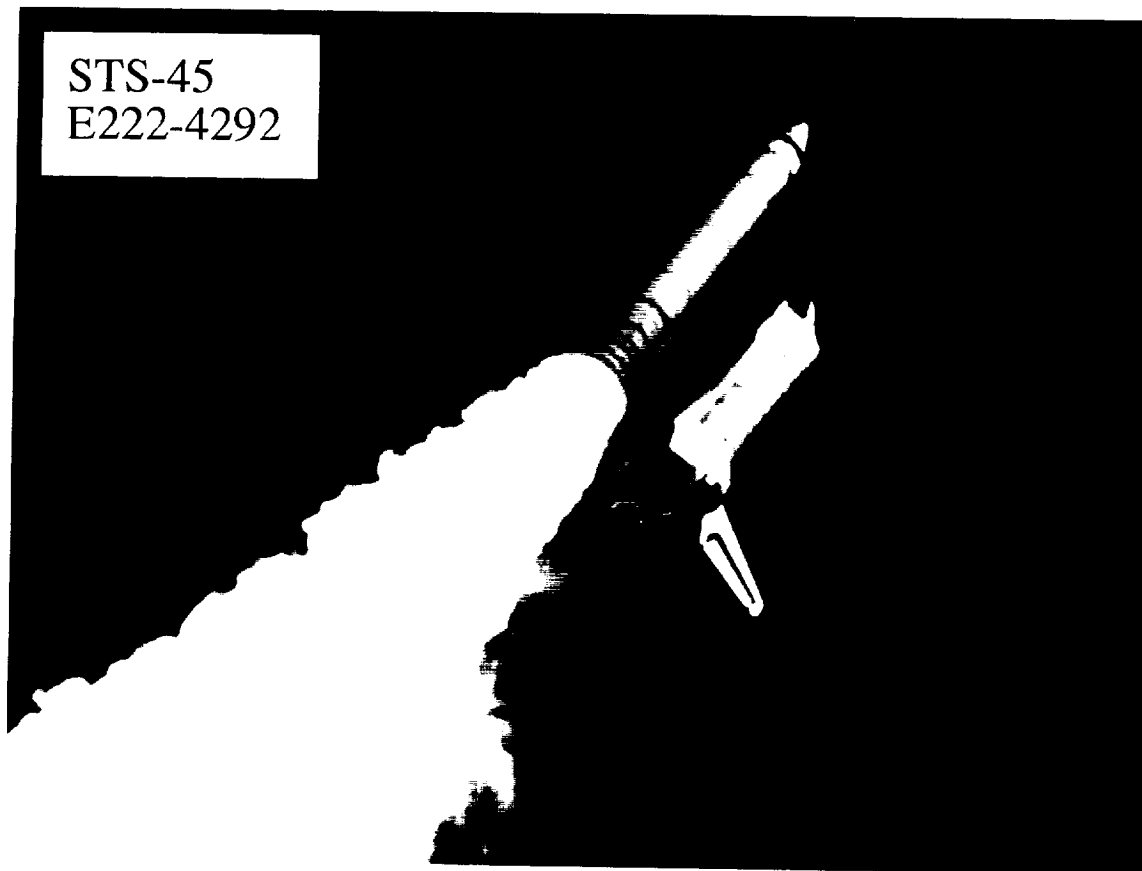


Figure 2.3.2 Flare in SSME Exhaust Plume at 38.334 seconds MET

Two flares were noted in the SSME exhaust plume at 20.006 and 38.334 seconds MET on camera E-222. See Figure 2.3.3. Flares in the SSME exhaust plume have been seen on previous missions. No follow up analysis has been requested.

2.3.3 Body Flap Motion during Ascent (Task #4) (Camera E-207)

Slight body flap motion was seen on E-207. When only slight motion is seen, attempted measurement of the displacement would be too inaccurate to generate useful results. In addition, the 180" lens used on the camera (E-207) showing the best view of the event was not of a high enough resolution to accurately quantify the motion.

Apparent body flap motion has been seen on most of the missions since reflight. This event will continue to be tracked on future missions.

2.0 Summary of Significant Events Analysis

2.3.4 Recirculation (Task #1) *(Camera E-205)*

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all of the previous missions. This event was conspicuously absent on most of the tracker camera films from STS-45 (due mostly to mission inclination). Only one camera showed even a slight amount of recirculation on this mission. Recirculation was first observed at 92 seconds MET and the end was noted at 111 seconds MET on Camera E-205. The time frame for this observed event is similar to those from previous missions.

See Appendix D Task #1 for a summary of recirculation start and stop times for all missions since reflight.

2.3.5 Linear Optical Effect *(Cameras ET-207, E-205 and E-207)*

On camera ET-207, a small white spot was seen to move quickly away from the SSME area at approximately 106 seconds MET.

On camera E-207, multiple linear optical distortions were noted.

The linear optical effect has been seen on previous missions and is thought to be associated with the atmospheric refraction generated by SLV shock waves.

2.0 Summary of Significant Events Analysis

2.3.6 Orange Pulses in SRB Plume Before SRB Separation (Task #9) (Cameras KTV-4A, KTV-5, KTV-13, ET-204, ET-207, ET-208, ET-212, E-204, E-205, E-207, E-208, E-212, E-218 and E-223)



Figure 2.3.6 Orange Pulse in LSRB Exhaust Plume Prior to Normal Plume Brightening

An orange pulse was noted in the LSRB plume between 117.62 and 118.02 seconds MET on several tracker cameras. See Figure 2.3.8. On cameras E-204, E-205, E-207, E-218 and E-223, three separate orange pulses were noted in the SRB exhaust prior to normal plume brightening.

A similar event was seen on STS-42. Frames preceding normal plume brightening on STS-45 were digitized and analyzed and then compared to those from STS-42. The objective was to characterize similarities between the two events. The analysis focused on the relative mean intensity and area of the SRB plume with respect to time. Results indicated that while minor pulses occurred on STS-42, they were of much lower intensities than STS-45.

2.0 Summary of Significant Events Analysis

2.4 On Orbit

2.4.1 Onboard Hasselblad ET Analysis - DT0-312 (Task #6); (Photographs 45-71-01 thru 45-71-38)

Thirty-eight 70mm Hasselblad photographs of the ET were taken on STS-45. The exposure and focus for nearly all of the photographs were excellent. The data back was turned on and timing information was available. These images show the closest views of the ET after separation of any mission to date.

All measurements were taken with an analog Nikon Shadowgraph and an Optronics Coscan. Both the LSRB and RSRB BSM burn scars on the O-give of the ET were visible. Nine divots in the LH2 intertank interface were noted. The largest of these measured 27.8 inches. The combination of high resolution imagery, good lighting conditions, excellent focus and valid timing data allowed a quantitative determination of the movement of the ET relative to the Orbiter. The rotation and translation rates, along with the separation velocity, are discussed in section 2.4.2 of the report.

2.4.2 ET Venting Analysis (Task #10)

The crew of STS-45 reported the appearance of venting from the ET aft umbilical and intertank areas during the time period following ET separation. Both the 70mm Hasselblad and the 16mm Arriflex motion picture camera were used to record images of the ET. Analysis of the handheld 70mm Hasselblad still camera and the 16mm Arriflex motion picture camera indicated the presence of vapor at the aft umbilical area. One Hasselblad frame (no. 45-71-031) appeared to show some intertank venting.

A review of the two earlier missions on which the ET contained similar amounts of excess propellant was conducted. No handheld photography or umbilical well films were taken on STS-8. Only the 35mm umbilical well film was available on STS-61C. Over the time period where the ET was in the field of view, there was no evidence of either the intertank or aft umbilical venting on STS-61C.

Analysis to correlate crew observed events to the actual photographs and film was implemented. An estimated timeline monitoring the sequence of events was generated and was included as Figure 2.4.2 (A).

All thirty-eight frames from the 70mm Hasselblad camera have been enlarged and printed. Twenty frames from the 16mm Arriflex were also enlarged and printed. In addition, selected images from both cameras have been digitized and processed on the VDAS System to enhance the observed venting. The Arriflex film sequence which showed the ET at full zoom was also converted from film to video. These images were registered, thresholded and pseudocolored to emphasize the venting seen at the aft umbilical area. No intertank venting was observed in this enhanced video.

The 70mm Hasselblads were taken over a period of 9 minutes, 24 seconds starting at approximately three and a half minutes after ET separation. Standard calculations of distance from the ET to the Orbiter and their relative velocity were performed. Knowing the focal length of the camera (250mm), the actual diameter of the ET (333 inches) and the ratio of the film frame size to the actual field of view, the Orbiter/ET distance was calculated over several frames. At frame 1, this distance was 554 meters (See Figure 2.4.2 (B)); at frame 38, the distance was calculated as 3272 meters. An average Orbiter/ET distance was also computed for the time frame when the 16mm Arriflex motion picture film showed the

STS-45 ET VENTING STUDY

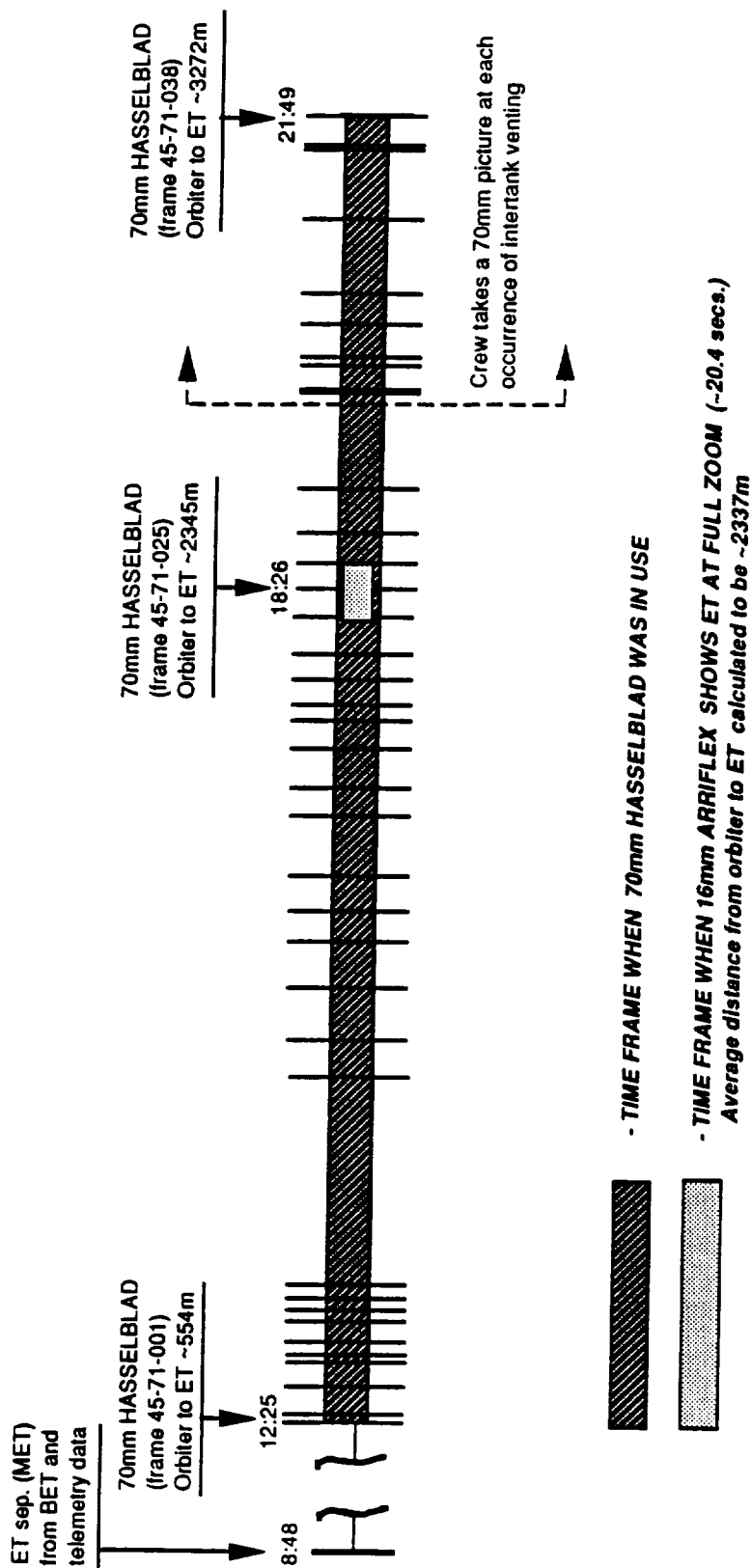


Figure 2.4.2. (A) ET Venting Study Timeline

2.0 Summary of Significant Events Analysis

ET at full zoom (a period of approximately 20 seconds). This average measure of the distance was calculated to be 2337 meters. This implies an overlap of as many as three Hasselblad frames (nos. 24, 25 and 26).

The aft umbilical venting angle was measured on five different digitized frames of the 16mm Arriflex motion picture film and was found to be varying between 51° and 86° . See Figure 2.4.2 (C). While the intertank venting was only captured on one frame of the Hasselblad film, this venting angle appears to agree with crew estimates of 90° to 150° . See Figure 2.4.2 (D). The actual measured angle on frame no. 45-71-031 was approximately 100° .

The tumble rate of the ET was calculated to be about 0.2° /second over the first seven minutes of photographic coverage and 2.7° /second over the final two minutes. This increase in the tumble rate appears to correspond with the crew's first observations of the intertank venting.

The rotation rate was calculated to be about 0.7° /second over the first minute of coverage. A maximum rotation rate of 3.0° /second occurred between the eight and nine minute mark of photographic coverage. This again appears to imply that the intertank venting reported by the crew did indeed affect the motion of the ET. See Figure 2.4.2 (E)

A CAD overlay of the ET was placed on the first frame of the 70mm Hasselblad sequence in order to locate the source of the aft umbilical venting. The best estimate of the projected origin was determined to be the LH2 umbilical area. Given limitations in the field of view of the photograph and the CAD system, the vent source could not be traced to a specific line.

2.0 Summary of Significant Events Analysis

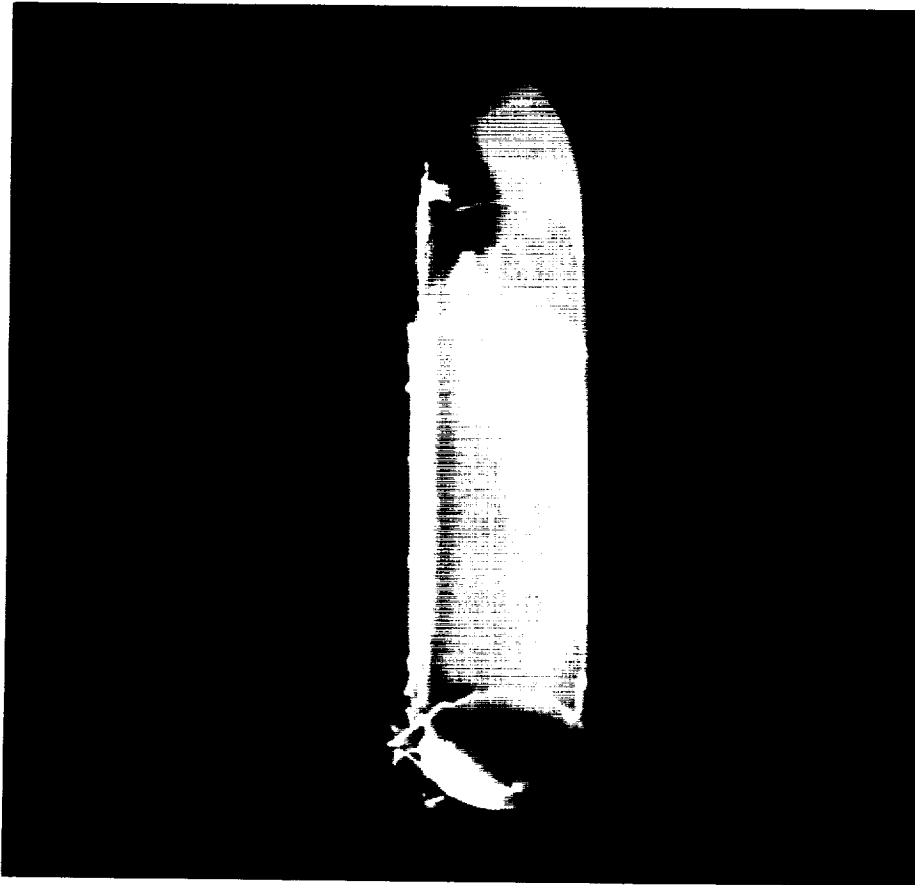


Figure 2.4.2 (B) **Earliest View of External Tank at 12 minutes, 25 seconds MET**
(70mm Hasselblad Frame No. 45-71-001)

The first Hasselblad image of the External Tank was taken from a calculated distance of approximately 554 meters. This is the earliest that the ET has been photographed and was the only Hasselblad image on which the aft umbilical venting could be seen, probably due to a combination of factors: Orbiter to ET distance; camera shutter speed; and exposure time. (Film type was Kodak color positive 5017.) Note that this view also clearly shows the burn scars on the O-give and four divots along the LH2 intertank interface. Reference the timeline in Figure 2.4.1 (A) for the observed sequence of events.

2.0 Summary of Significant Events Analysis

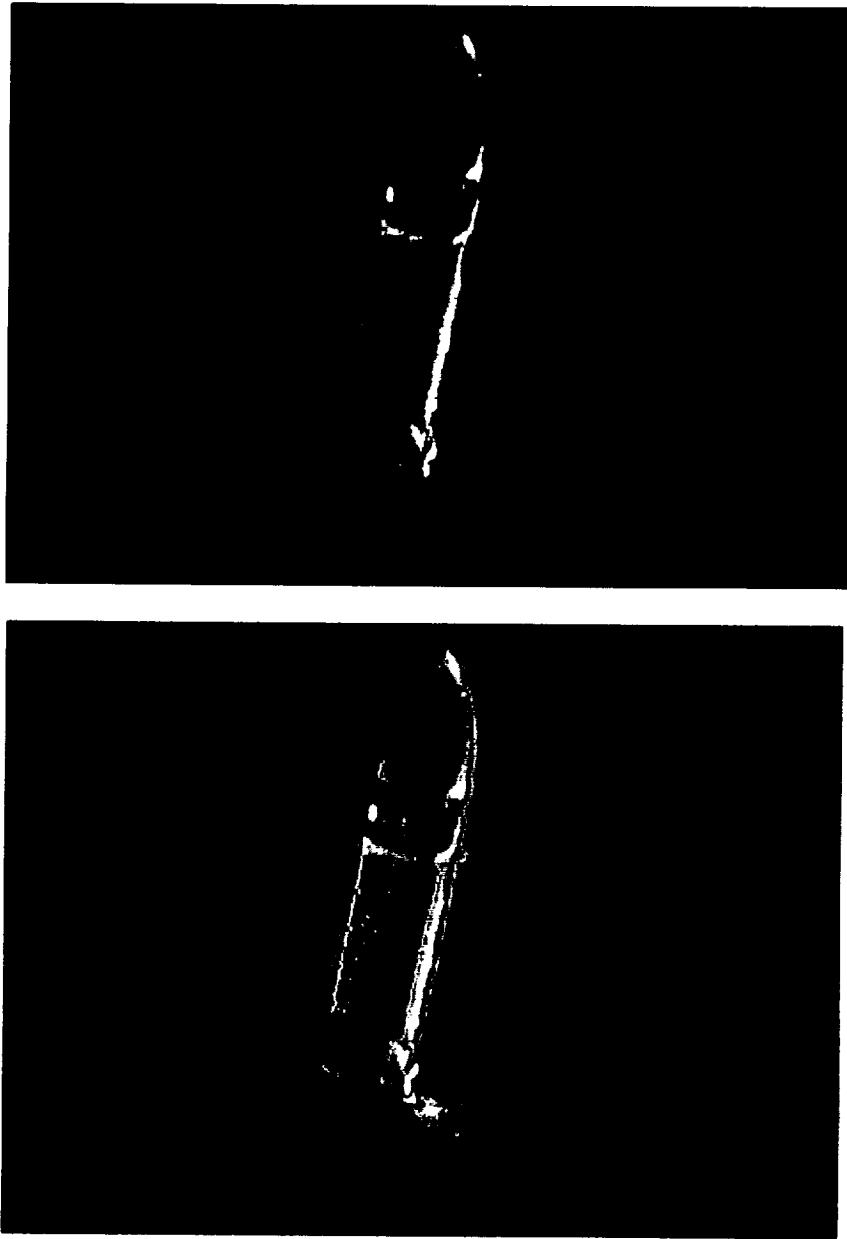


Figure 2.4.2 (C) **Venting Observed from Aft Umbilical Areas at
Approximately 18 minutes, 30 seconds MET**
(16mm Arriflex Frame F510 - 1323)

These images of the same frame show venting from the aft umbilical area as seen by the 16mm Arriflex motion picture camera. The top image shows the original frame, while the lower one emphasizes the venting with pseudo-color. While the External Tank was within the field of view at full zoom (a period of approximately 20 seconds), the aft umbilical venting appeared as three distinct pulses. An enhanced film-to-video conversion of this sequence of images showed the actual venting to be continuous. No intertank venting was observed on this film.

2.0 Summary of Significant Events Analysis



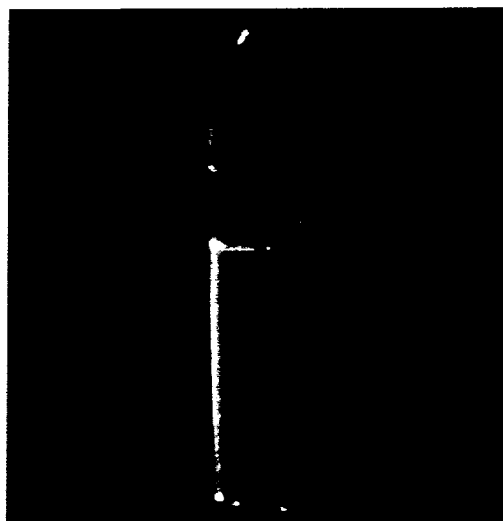
Figure 2.4.2 (D) **Intertank Venting seen at 20 minutes, 2 seconds**
MET
(70mm Hasselblad Frame No. 45-71-031)

Processing enhancements to the 70mm Hasselblad imagery revealed one frame where the intertank venting reported by the astronauts was visible. The frame appeared to show the projected source as being in the vicinity of the intertank umbilical carrier plate area. Crew estimates of the venting cone angle varied between 90° and 150°. The intertank venting may have been the reason that the ET rotation rate seemed to change substantially during this period of time. See Figure 2.4.2 (E) for more detail.

2.0 Summary of Significant Events Analysis



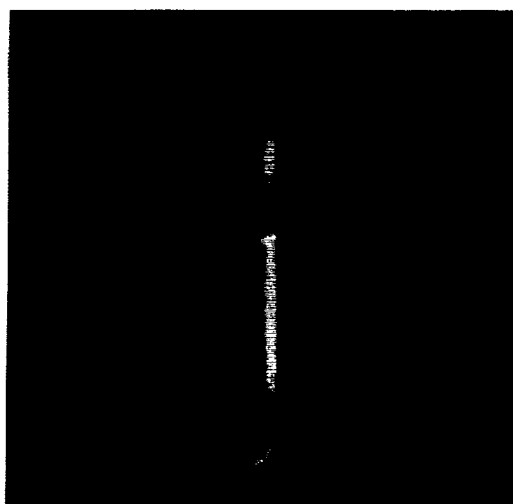
Frame 45-71-031
20 minutes, 2 seconds MET



Frame 45-71-034
20 minutes, 32 seconds MET



Frame 45-71-035
21 minutes, 4 seconds MET



Frame 45-71-036
21 minutes, 34 seconds MET

Figure 2.4.2 (E)

**Sequence of Four Images Showing Change in the
Rotation Rate of the ET at 21 minutes MET**
(70mm Hasselblad Frame Nos. 45-71-031, 034, 035, 036)

Calculated rotation rates of the External Tank appeared to vary while the last ten Hasselblad frames were shot. This sequence of photographs compares the rotational position of the ET as a function of time. The intertank venting seen by the crew may have been a factor in this observed change of the ET rotational velocity. Assuming that the Orbiter's motion stayed relatively constant with respect to the External Tank, the ET also appeared to be wobbling (in a direction normal to the field of view) over this sequence of frames. Reference Appendix D Task #10 for details.

2.0 Summary of Significant Events Analysis

2.5 Landing Events

2.5.1 SSME #3 Beta Blanket Tear

The post-landing inspection of the Orbiter showed tears in the SSME #3 beta blanket. Similar damage had been seen on the SSME #2 beta blanket on STS-39. This event is not considered anomalous.

2.5.2 Damage to RCC on Right Wing and Nose Area (Task #11)

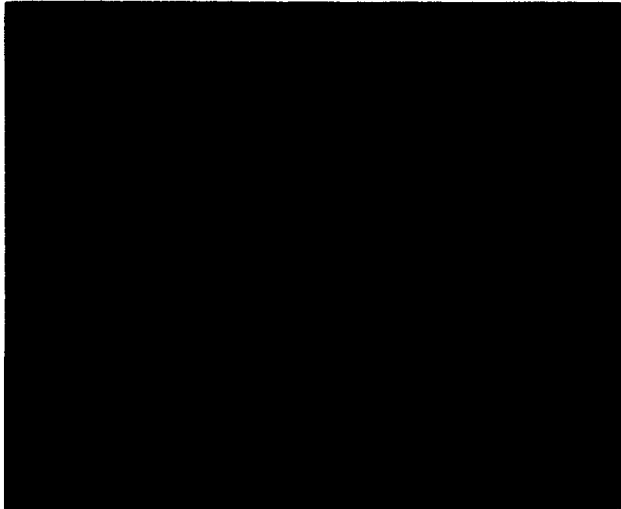
The post-landing inspection of the Orbiter revealed damage to the lower right nose area (tile nos. V070-39015-211 and V070-39015-212) and to the RCC panel #10 near the leading edge of the right wing. A review of launch tracker films E-052, E-054, E-057, E-059, E-205 and E-207 and all the landing videos was conducted to determine whether or not the damage could have been attributed to a previously seen event. No apparent debris source was seen on the films that might have led to the damage. Figure 2.5.2 (A) shows a general view of the damaged areas. Figure 2.5.2 (B) shows detailed views of the RCC damage.



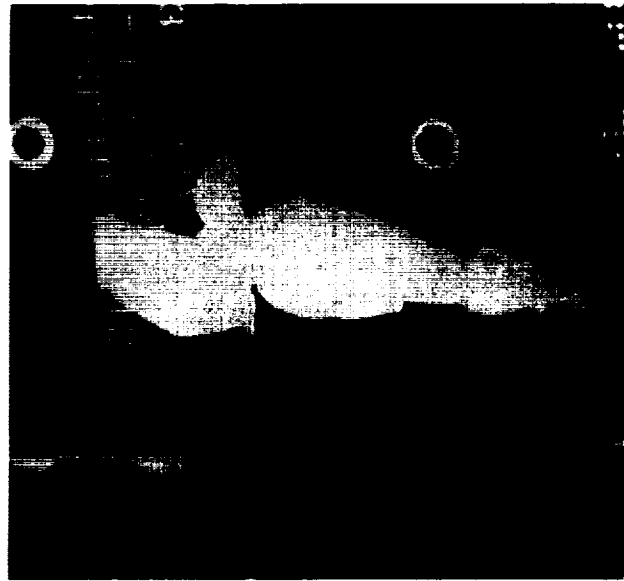
Figure 2.5.2 (A) Tile Damage Locations on the Orbiter

This photograph taken during the post-landing inspection of the Orbiter shows a general view of the area where RCC damage was seen. See Figure 2.5.2 (B) for more detailed views of the damage.

2.0 Summary of Significant Events Analysis



Right Wing Damage



Nose Area Damage

Figure 2.5.2 (B) RCC Damage to the Orbiter Right Wing and Nose Area

The photographs in Figure 2.5.2 (B) show the extent of the damage on both the leading edge of the right wing and the underside of the nose area. The strike on the lower right side of the Orbiter (Tile # V070-39015-211) was analyzed. A section of the black outer layer of the tile was pressed into the white inner layer from some object striking the tile; however, no residue was found in the cavity.

Post-retrieval inspection of the SRBs also revealed two areas of damage on the aft skirt area of the RSRB.

No definitive sources of debris that might have caused damage were identified from the tracker camera films at either launch or landing.

2.5.3 Debris in Umbilical Well Doors

The post-landing inspection of the Orbiter also revealed a pyro detonator booster located in the right ET door aft hinge cavity along with smaller metal debris. The problem report generated by this event is located in Appendix H.

2.0 Summary of Significant Events Analysis

2.5.4 Landing Sink Rate Analysis (Task #3)

2.5.4.1 Landing Sink Rate Analysis Using Film (Camera E-1001)

Camera EL-009 was used to determine the main landing gear sink rate. This particular view showed the aft side of the orbiter from the end of the runway. A point on the top and bottom of the right main landing gear was chosen for each frame. Four points were also chosen at the left and right edges of the runway for the first and last frames. These were digitized to detect any significant camera motion. Raw data was corrected for the vertical change in scale at each frame. The wheel position was computed and a linear regression was applied on the normalized vertical distance vs. time data to determine actual sink rate. This rate was determined to be 2.0 ft/sec.

Nose gear touchdown was determined using camera ML-005. Points on top of both the left and right main landing gear (used for scale and to eliminate camera motion) as well as a point on the nose wheel were digitized for each frame. Raw data was corrected for the vertical change in scale at each frame using the known distance between the two main landing gear wheels. The nose wheel position was computed and a linear regression was applied on the normalized vertical distance vs. time data to determine actual sink rate. This rate was determined to be 2.9 ft/sec.

See Appendix D Task #3 for details.

2.5.4.2 Landing Sink Rate Analysis Using Video (Camera KTV-33)

Data from camera KTV-33 was used to determine the sink rate of the main gear. An area near the nose gear was used as a reference scale. The position of the main gear as a function of time was found by taking the difference between the raw vertical positions of the main landing gear and the edge of the runway with the same X coordinate over 32 frames. Using the scale as a function of time, these differences were converted to feet. A least squares regression line was calculated from the data and the slope was used as the average sink rate. This rate was found to be 1.0 ft/sec.

The sink rate for the nose gear was also calculated using 32 frames digitized from camera KTV-33. A linear regression of the data was calculated in the same manner as above. The slope of this line was used as the sink rate and was found to be 3.0 feet per second.

See Appendix D Task #3 for details.

Results from the film analysis are considered better than video because of the higher spatial resolution. The quantization error inherent in the use of the video makes this analysis insufficient to meet the 0.1 feet per second precision required by the OMSRB.RCNSD500002DV51.P.001.

2.6 Other Normal Events

Other events seen on the STS-45 launch views that have been seen on previous shuttle flights include:

Overpressure wave during SRB ignition, debris in the exhaust cloud on the MLP after liftoff, vapor from both SRBs' stiffener rings, ET aft dome outgassing, charring of the ET aft dome, ice and vapor from the T-0 umbilical disconnects, and SRB plume brightening prior to SRB separation.

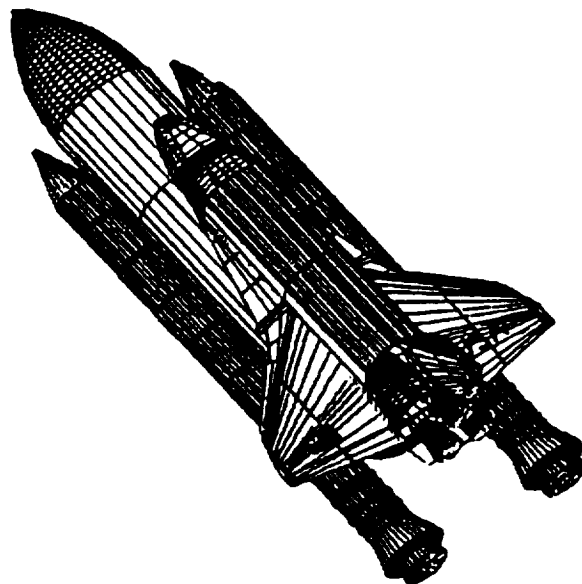
Appendix B. MSFC Photographic Analysis Summary



National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT STS-45



ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

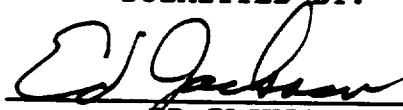
STS-45

FINAL

PREPARED BY:

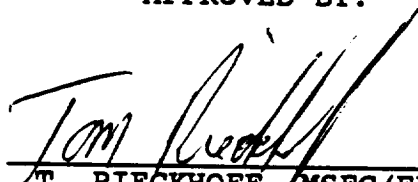
J. HIXSON, D. BUSING, B. VIGER, W. LANGLOIS
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

SUBMITTED BY:



ED JACKSON
MANAGER, LAUNCH AND FLIGHT OPERATIONS/ROCKWELL/HSV

APPROVED BY:



T. RIECKHOFF, MSFC/EP55
B. LINDLEY-ANDERSON, MSFC/EP55

STS-45 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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* Photographs in the individual camera assessments are representative photographs and are not necessarily photographs taken from this particular launch.

April 15, 1992

I. INTRODUCTION

Space Shuttle Mission STS-45, the eleventh flight of the Orbiter Atlantis, was conducted March 24, 1992 at approximately 7:14 A.M. Central Standard Time from Launch Complex 39A (LC-39A), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage was provided and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39A perimeter sites, onboard, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-45 included, but were not limited to the following.

- a. Overall facility and shuttle vehicle coverage for anomaly detection
- b. Verification of cameras, lighting and timing systems
- c. Determination of SRB PIC firing time and SRB separation time
- d. Verification of Thermal Protection System (TPS) integrity
- e. Correct operation of the following:
 1. Holddown post blast covers
 2. SSME ignition
 3. LH2 and LO2 17" disconnects
 4. GH2 umbilical
 5. TSM carrier plate umbilicals
 6. Free hydrogen ignitors
 7. Vehicle clearances
 8. GH2 vent line retraction and latch back
 9. Vehicle motion

There were two special test objectives for this mission.

- a. SRB holddown post shoe rotation quantification
- b. DTO-0312, ET photography after separation

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-eight of fifty-nine requested cameras as well as video from twenty-three of twenty-three requested cameras. The following table illustrates the camera data received at MSFC for STS-45.

CAMERA DATA RECEIVED FOR STS-45

	<u>16mm</u>	<u>35mm</u>	<u>70mm</u>	<u>Video</u>
MLP	26	0	0	3
FSS	7	0	0	3
Perimeter	3	3	0	6
Tracking	0	15	0	11
Onboard	3	0	1	0
Totals	39	18	1	23

A detailed individual motion picture camera assessment is provided as Appendix B. Appendix C contains detailed assessments of the video products received at MSFC.

a. Ground Camera Coverage:

Photographic coverage of STS-45 was considered good. However, the long range trackers were partially obscured by clouds. Cameras E-9 and E-34 both experienced a speed malfunction prior to liftoff. Camera E-220 did not record data due to a film magazine problem.

b. Onboard Camera Assessment:

A camera was flown on each SRB forward skirt to record the main parachute deployment. Both cameras operated properly. However, camera E-302 onboard the left SRB did not record SRB water impact. Also, the astronauts recorded the ET after separation with 70mm and 16mm hand-held cameras to evaluate ET TPS integrity. Thirty-eight frames of the ET were recorded on the 70mm film.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These included pad debris rising and falling as the vehicle lifts off, debris induced streaks in the SSME plume, and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detectors, purge barrier material and SRB thermal curtain tape.

b. Holddown Post M-4 Stud Hang-up:

Figure one is a film frame taken from camera E-7 showing holddown post M-4 stud hang-up. Approximately 12 inches of the stud appears to remain extended until the SRB aft skirt clears the stud. The stud then moves 1.5 inches laterally, at which time it then drops into the HDP bolt catcher. The stud pulled loose four pieces of EPON shim material from the base of the shoe as the vehicle lifted off.

c. SRB Holddown Post M-7 Debris:

Figure two is a film frame taken from camera E-11 showing the second of two events of frangible nut material falling from holddown post M-7 hole. These debris are typical of previously observed frangible nut material.

d. Debris From SRM Plume:

Figure three is a film frame showing one piece of debris noted coming from the SRM plume during ascent at 084:13:14:53.06 UTC. This debris is possibly thermal curtain tape.

e. ET Divots:

The 70 mm photography of ET after separation showed several TPS divots. The photography covered all sides of the ET. Two large divots were noted in the char on the aft dome. Several divots were located at the intertank/LH2 tank interface near the +Y axis. These divots are shown in figure four.

f. ET Venting:

Venting of the ET at the 17" disconnect and intertank areas was reported by the astronauts while performing DTO-312. Venting of the LH2 17" disconnect was recorded on film. This venting was recorded on the 16mm arriflex camera and appeared to pulsate in intensity. No timing was available on this film. One frame (001) of the 70mm Hasselblad camera also recorded this venting at 13:26:05 UTC.

A comparison of the venting plume was made with a plume resulting from a 700 SCIM leak of N2O4 from the Orbiter's RCS on STS-42. Figures five and six provide a side-by-side comparison of these two plumes from similarly scaled images. The ET venting is from frame 1323 of the 16mm film. The RCS plume size is unknown since it expands off the frame. It shows that the ET plume is lesser than the RCS plume. However, it should be noted that differences in background and image quality may affect the visible plume size.

An attempt was made to locate the source of the plume at the LH2 disconnect. The 16mm film did not provide the required resolution. Figure seven is a CAD model overlay of frame 001 from the 70mm film. Figure eight represents the plume boundaries and bisector normal to the viewing vector. Figure nine shows the disconnect with an intersecting plane defined by the plume bisector and view vector. Figure ten is a disconnect layout drawing with the resulting intersection line of the disconnect and the plane showing the measured location of the venting source.

A review of previous flight film showed that no venting at either the intertank or disconnect areas has ever been recorded. Table IV-1 provides a summary of this review along with DTO acquisition times after ET separation. It should be noted that the ET was visually acquired much earlier on this mission than on previous flights.

TABLE IV-1

ET VENTING PHOTOGRAPHIC SUMMARY

<u>Mission</u>	<u>DTO-312 TIME (Sec after sep.)</u>	<u>DTO-312 Observations</u>	<u>Umbilical Well* Observations</u>
STS-28	883	No venting noted	No venting noted from disconnects
STS-29	850	No venting noted Good view of GUCP	-
STS-32	-	-	No venting noted from disconnects
STS-34	No timing	No venting noted	-
STS-35	-	Film not available	-
STS-37	No timing	No venting noted Good view of GUCP	-
STS-39	-	Film not available	-
STS-40	No timing	No venting noted Good view of GUCP	No venting noted from disconnects
STS-42	883	No venting noted	-
STS-43	911	No venting noted Good view of GUCP	-
STS-45	745	Venting observed from LH2 disconnect	-

* Coverage from ET sep. to approximately separation + 2 minutes

A review of the STS-45 camera usage timeline shows that the 16mm arriflex camera was used during the time span that the 70mm stills were taken. The 16mm motion picture camera recorded the venting during this time while the venting was not apparent on the stills. Therefore it cannot be stated from film that no venting occurred since all previous DTO film reviewed were of 70mm stills.

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times were determined from cameras which view the SRB holddown posts numbers M-5 and M-6. These cameras record the explosive bolt combustion products.

POST	CAMERA POSITION	TIME (UTC)
M-1	EX1	084:13:13:39.999
M-5	E-12	084:13:13:40.000
M-6	E-13	084:13:13:40.001

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 31.4 inches. Figure eleven is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. These data were derived from camera E-79.

c. SRB Separation Time:

SRB separation time for STS-45 was determined to be 084:13:15:48.14 UTC taken from camera E-207.

d. SRB Holddown Post Shoe Rotation Study:

A study was performed on this mission to determine the aft skirt/shoe rotation effects at T-Zero due to the radial biasing of the MLP holddown post to 0.060 inches.

Cameras EX1, EX4, E-27 and E-28 were used to provide close-in coverage of the shoes and holddown posts M-1, M-5, M-3 and M-7, respectively.

Figure twelve shows the locations of the cameras and holddown posts and direction of "horizontal motion" relative to the attached plots.

Figures thirteen and fourteen show the target positions of the motion data taken relative to a stationary target on the MLP. Figure thirteen represents posts M-1 and M-5. Figure fourteen

represents posts M-3 and M-7.

The following table provides the RMS data accuracy for each post measured in inches.

<u>Post</u>	<u>Horizontal</u>	<u>Vertical</u>
M-1	+.018	+.017
	-.017	-.015
M-3	+.013	+.012
	-.014	-.002
M-5	+.024	+.018
	-.023	-.017
M-7	+.012	+.012
	-.012	-.013

The motion data are presented in figures fifteen through twenty-six. These data have been filtered to remove the noise from the interactive digitization process.



Figure 1

Holddown Post M-4 Stud Hang-up



Figure 2

Frangible Nut Material From Holddown Post M-7

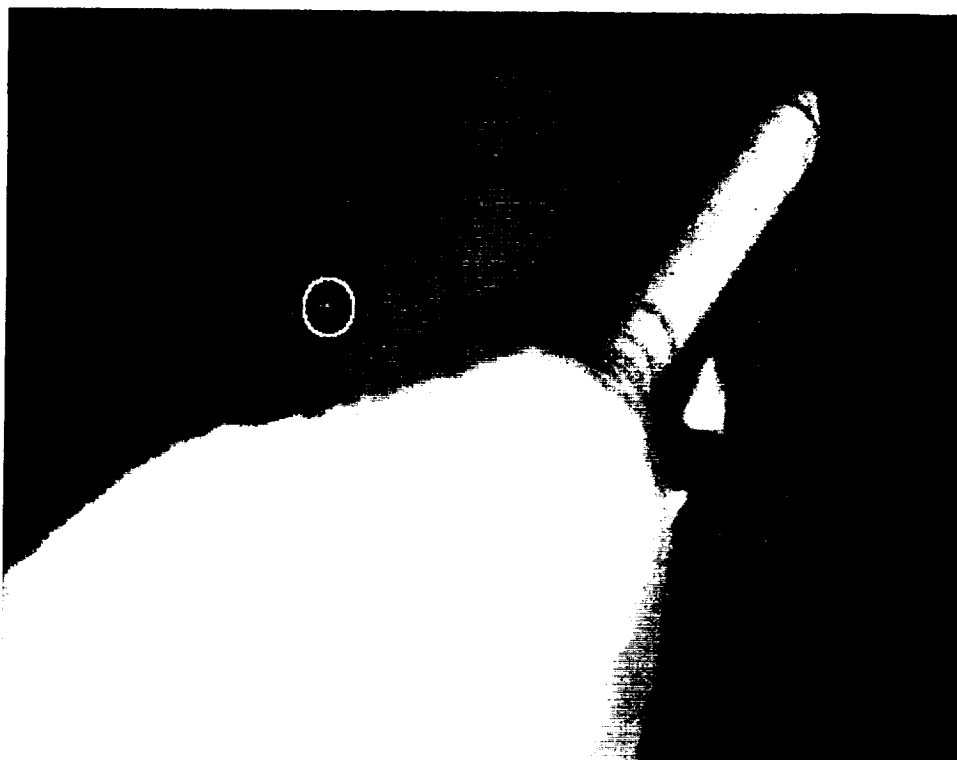


Figure 3
Debris From SRM Plume

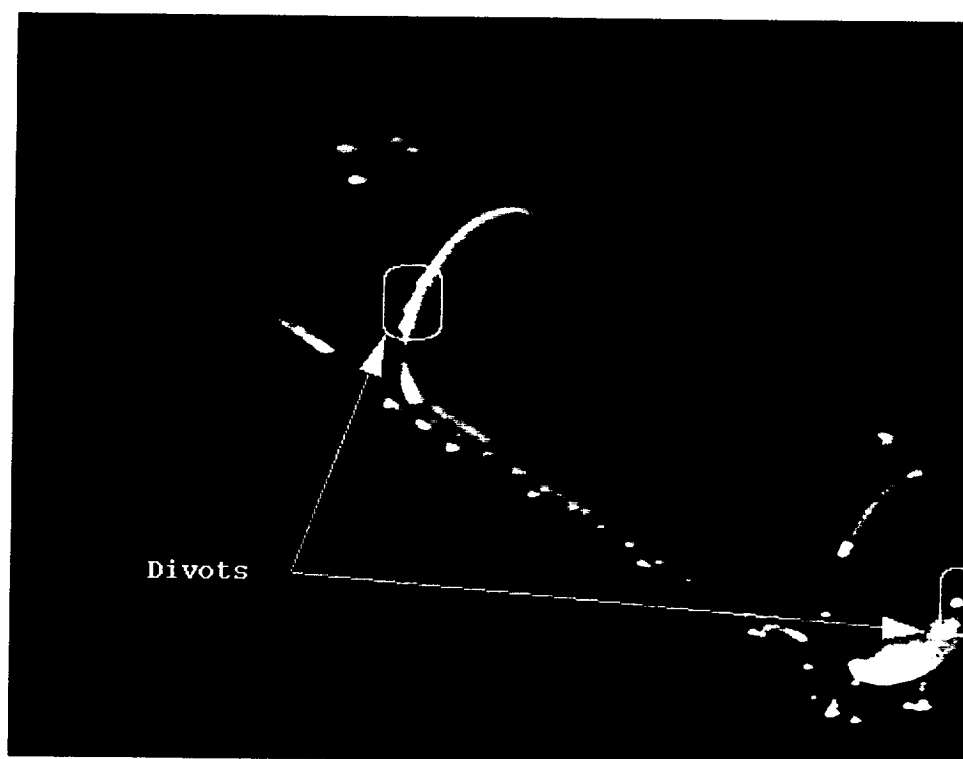


Figure 4
EF Divots

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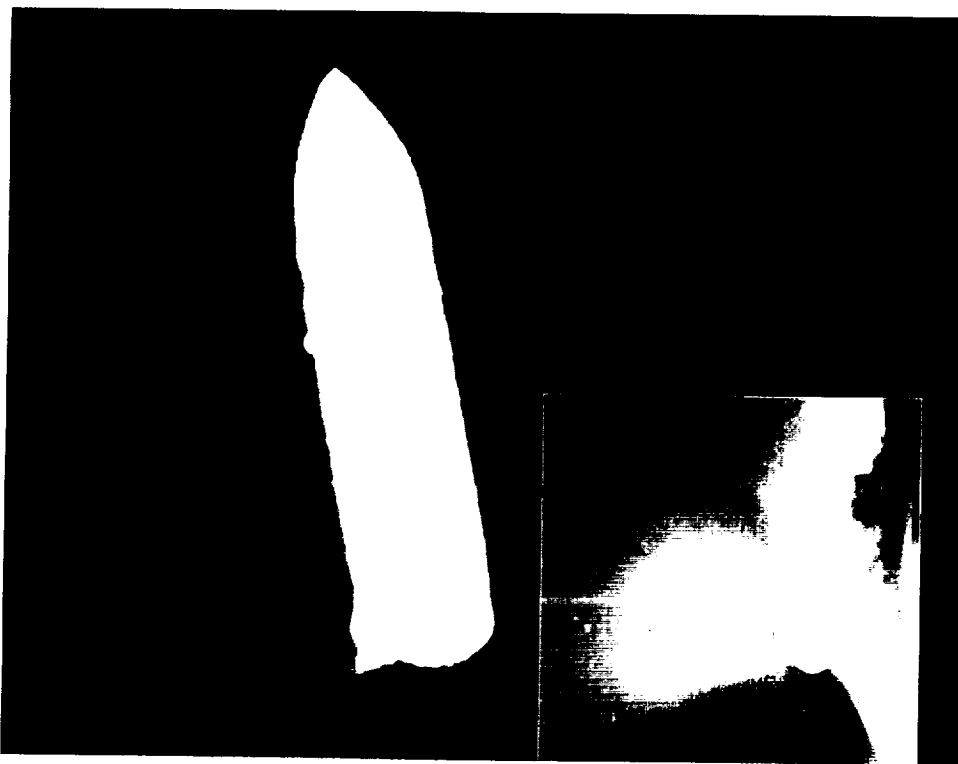


Figure 5
Plume Comparision

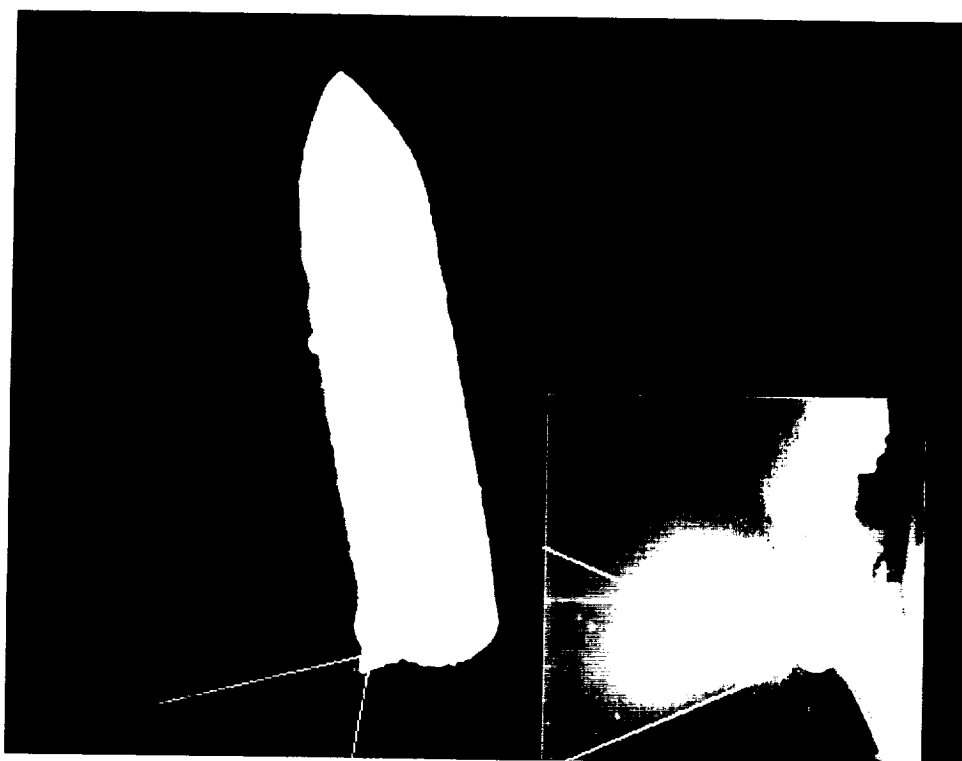


Figure 6
Plume Comparision

ORIGINAL PAGE
COLOR PHOTOGRAPH

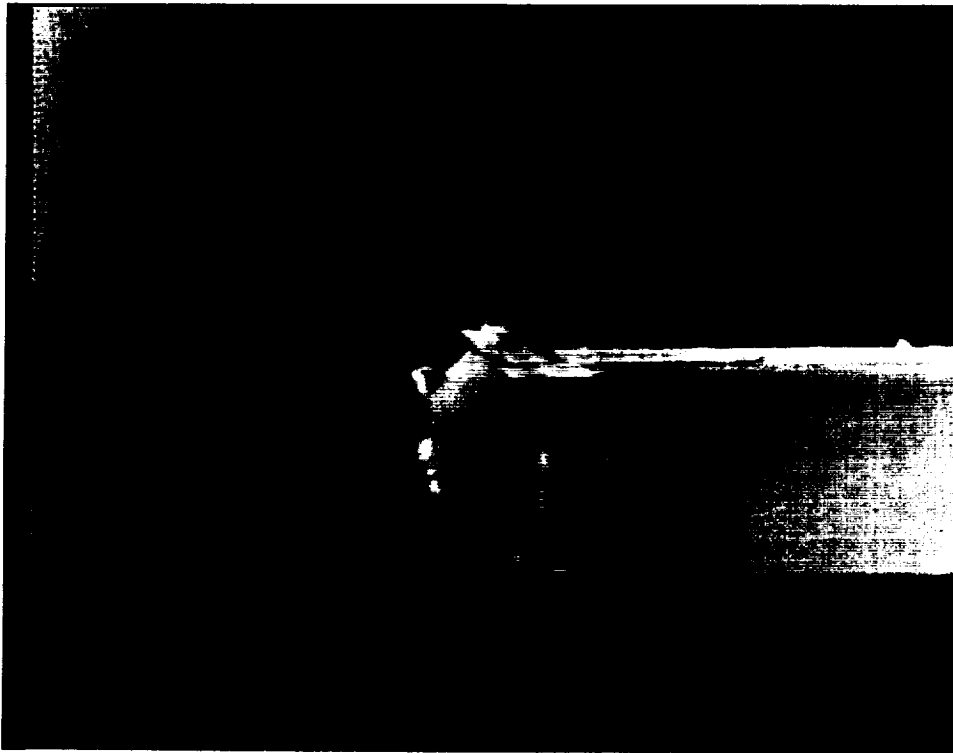


Figure 7

CAD Model Overlay of Frame 001



Figure 8

Representation of Plume Boundaries

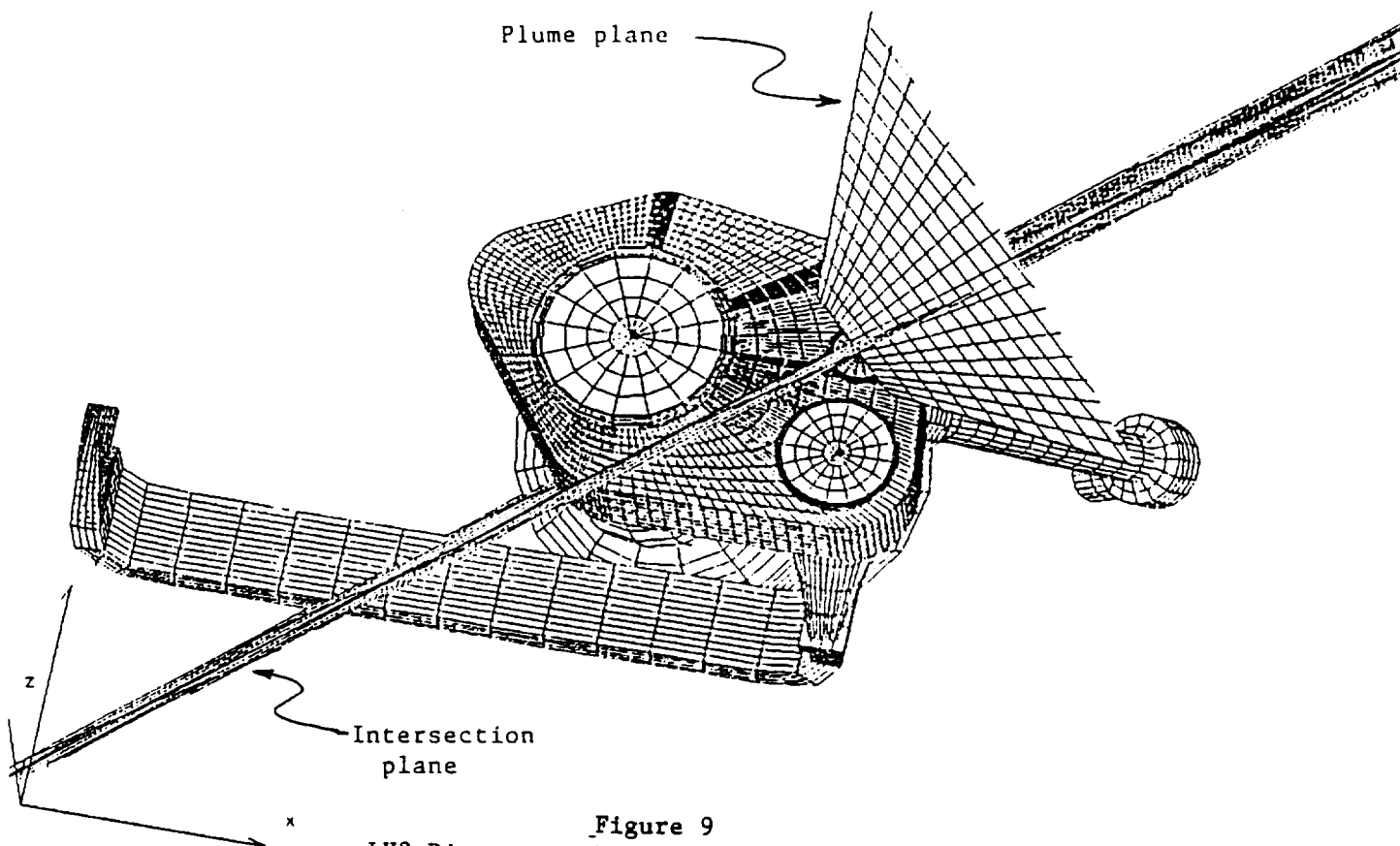


Figure 9
LH2 Disconnect With Intersection Plane

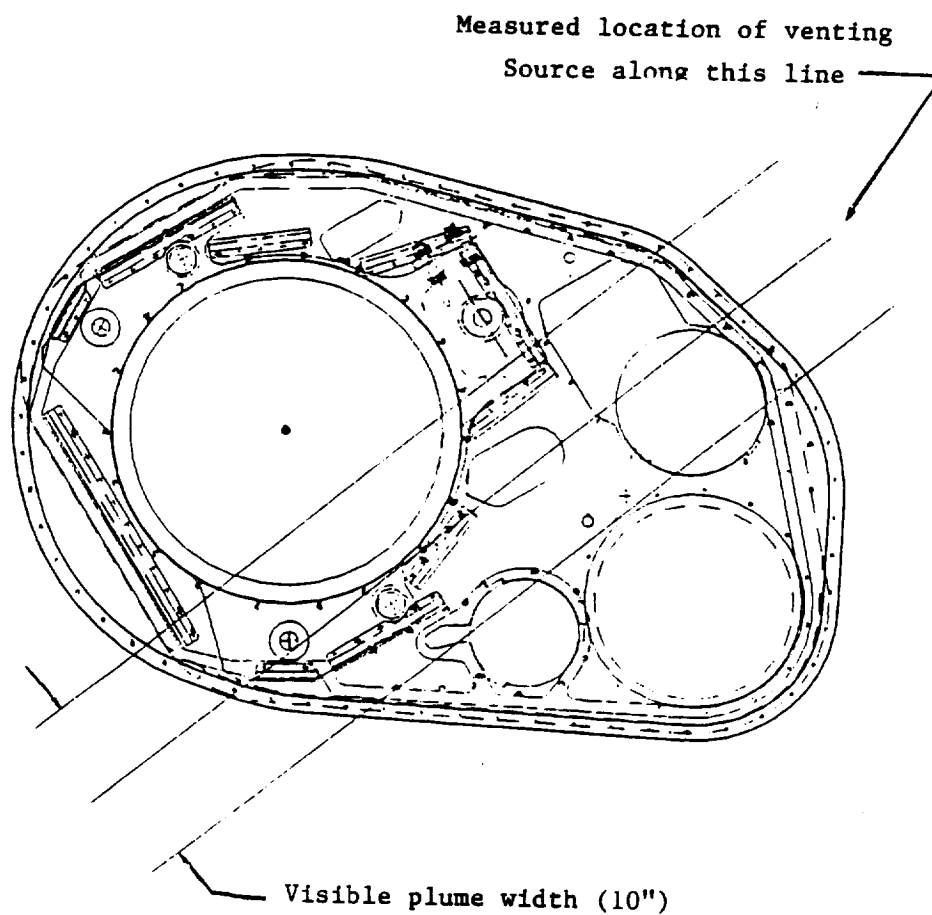


Figure 10
LH2 Disconnect Layout

ET TIP DEFLECTION

ETS-45

08:03:24 2-APP-92

—40PC MOTION

—15PC MOTION

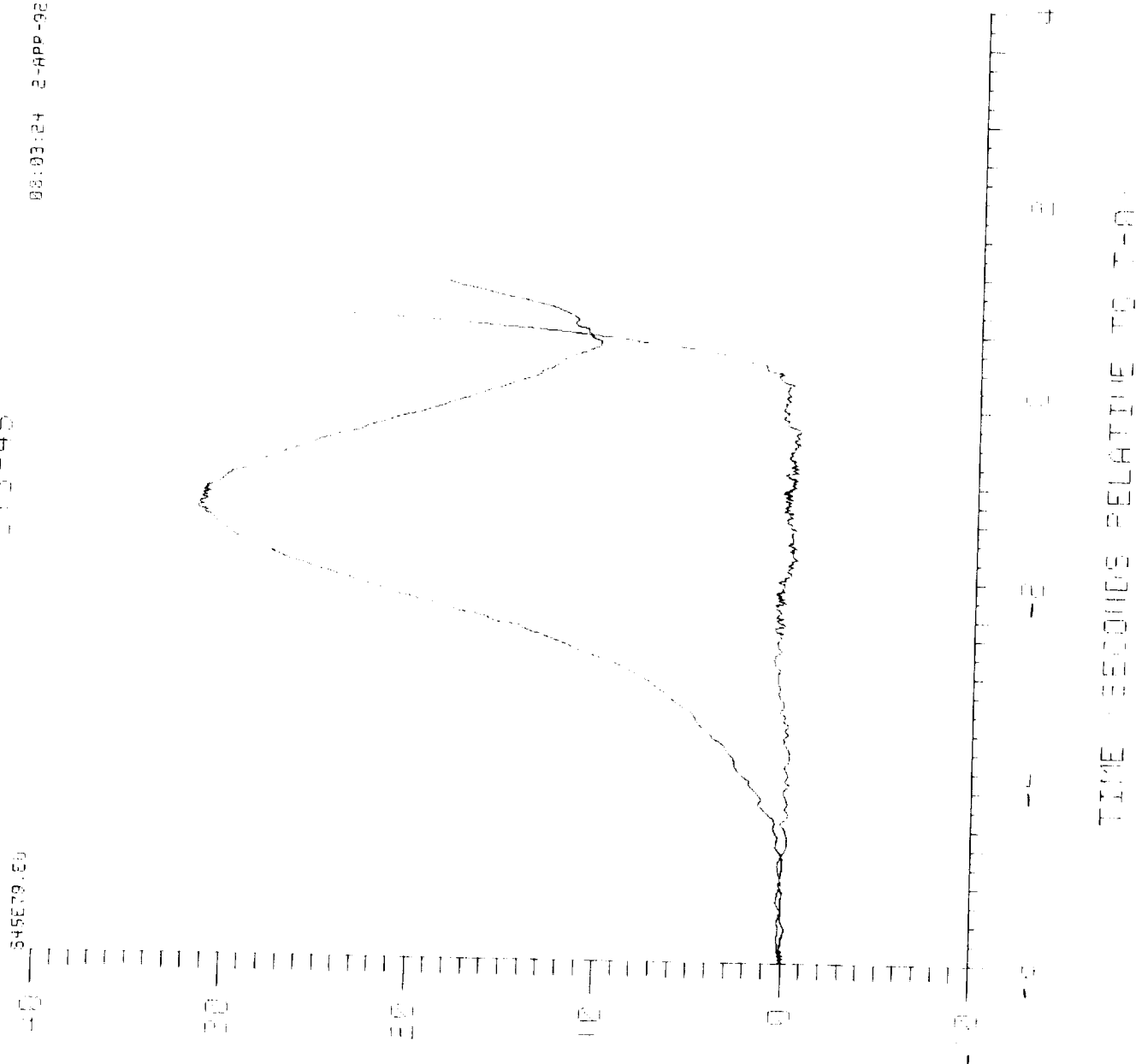
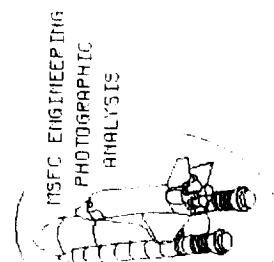


Figure 11



HOLDDOWN POSTS AND CAMERA ORIENTATION

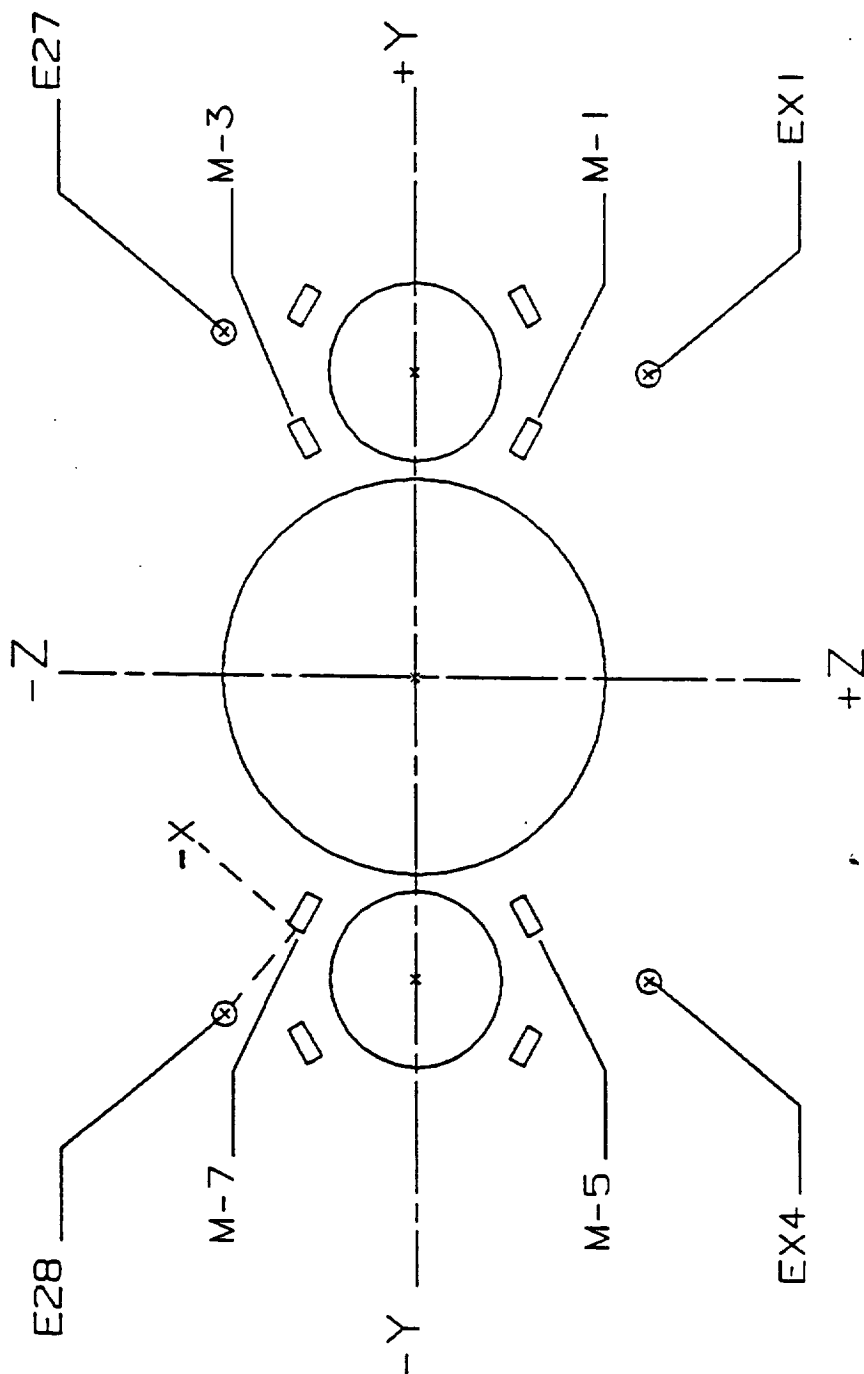


Figure 12
Camera Locations

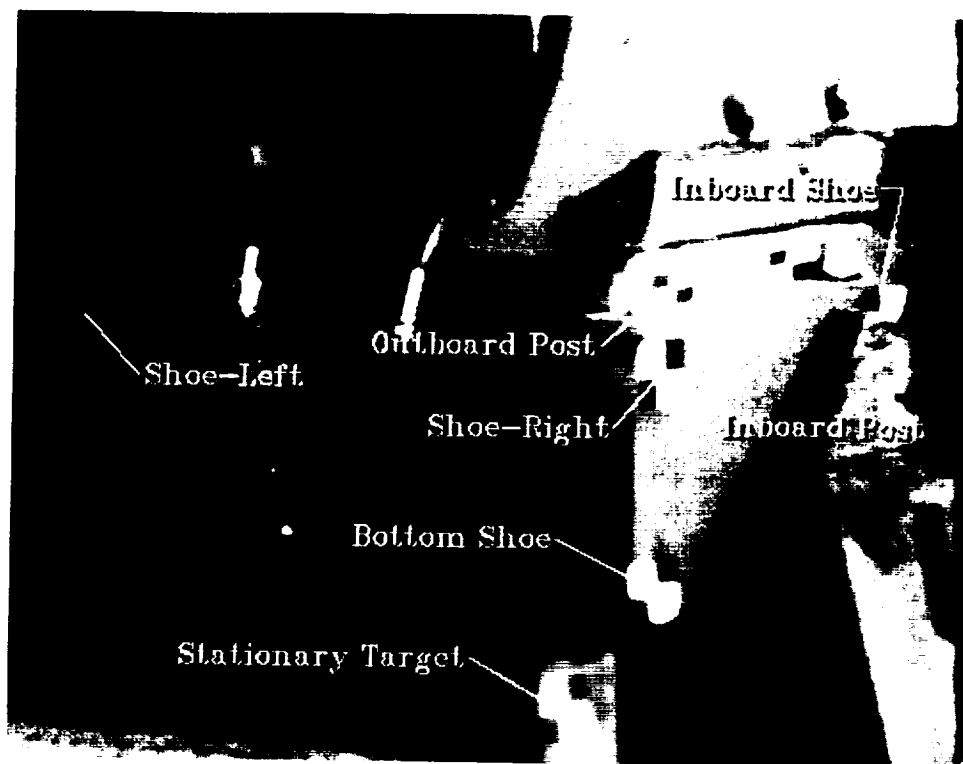


Figure 13

Target Positions of Holddown Post M-1 and M-5

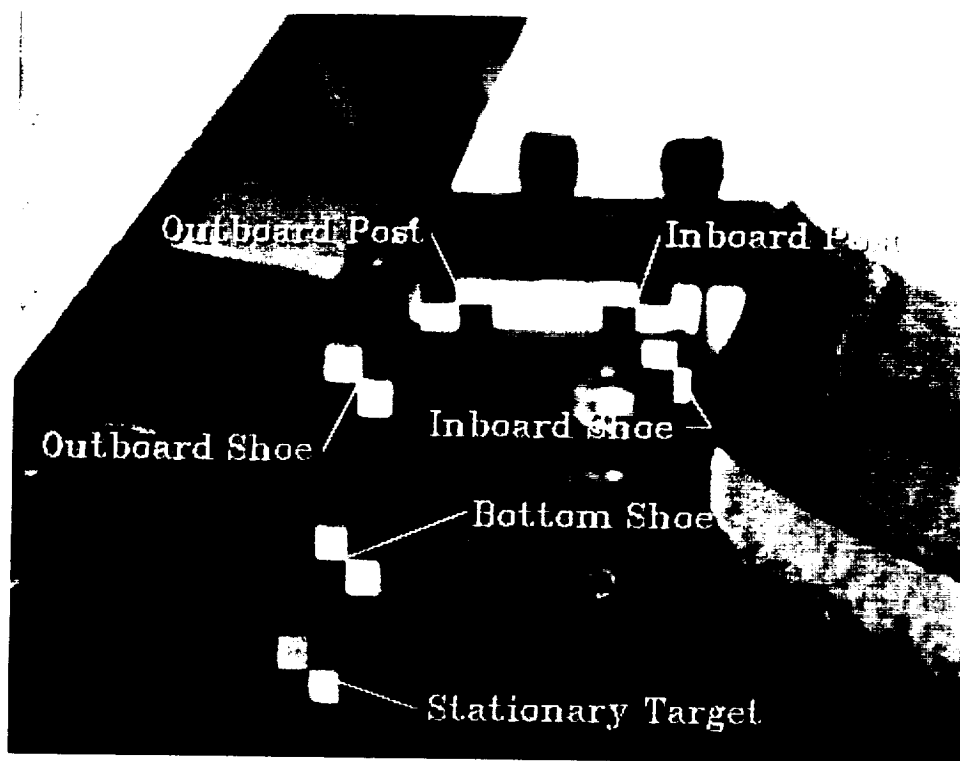


Figure 14

Target Positions of Holddown Post M-3 and M-7

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A COLOR PHOTOGRAPH

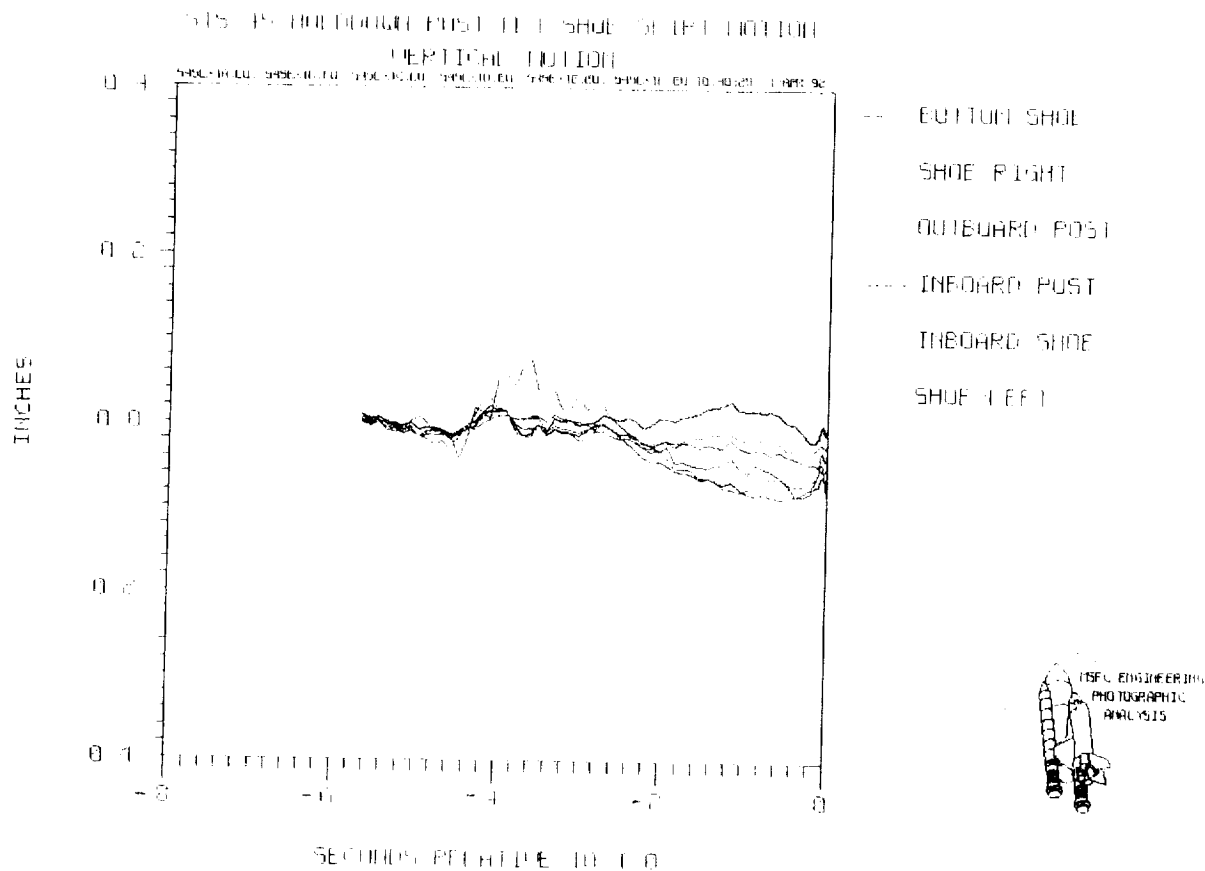


Figure 15

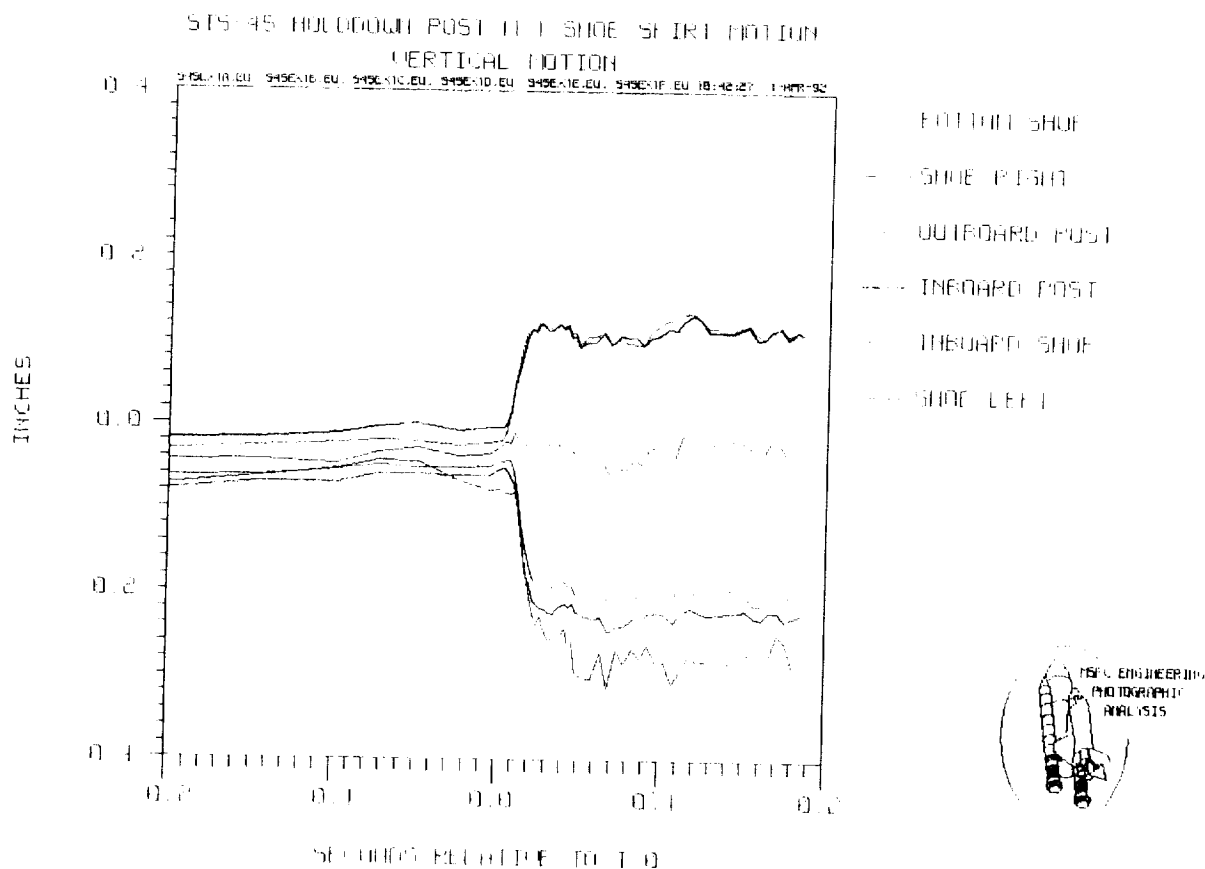


Figure 16

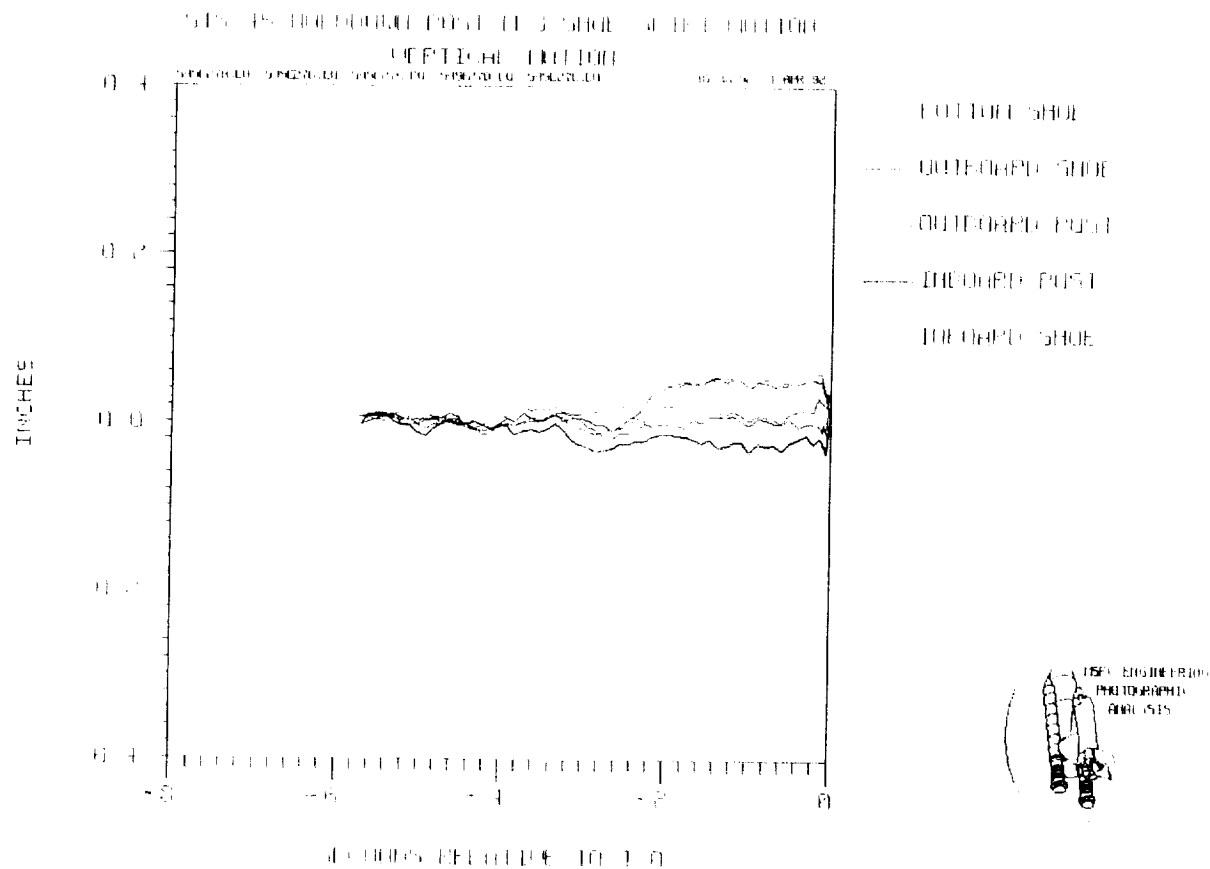


Figure 17

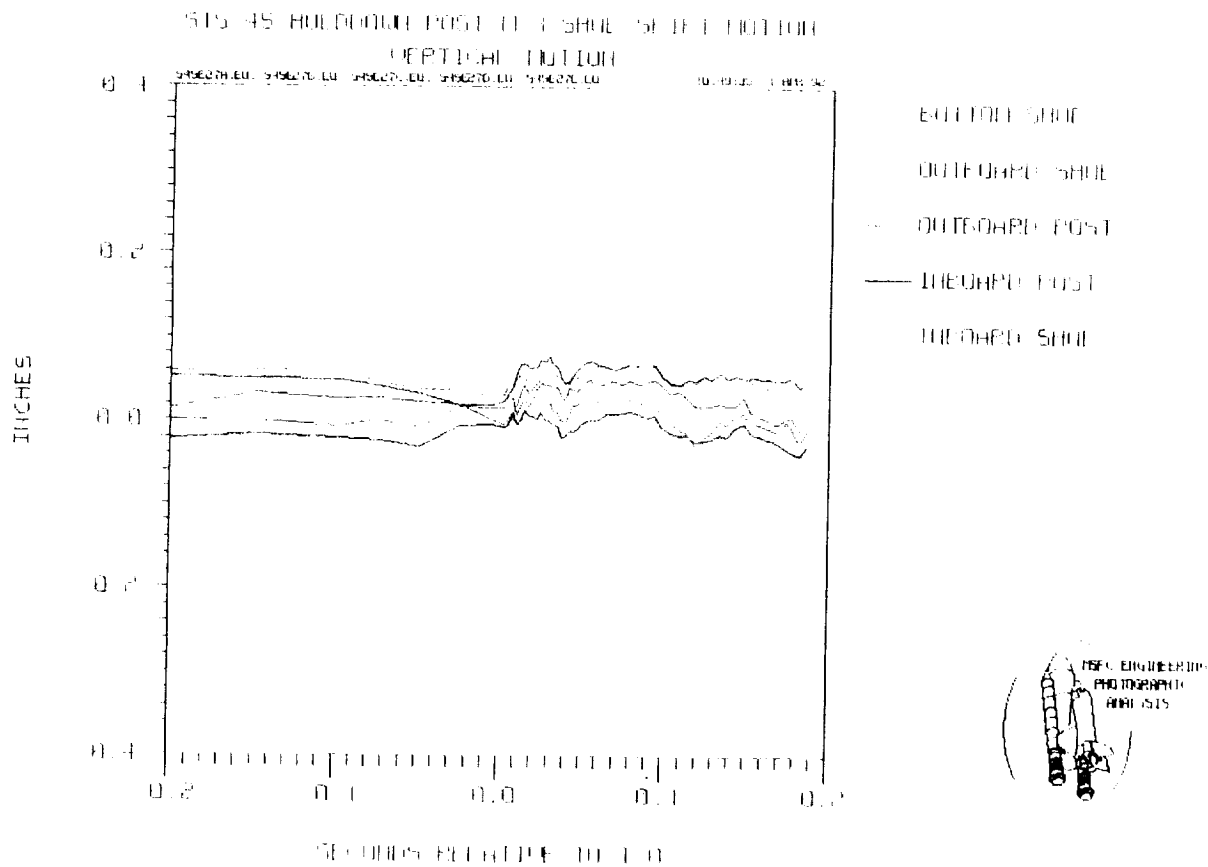


Figure 18

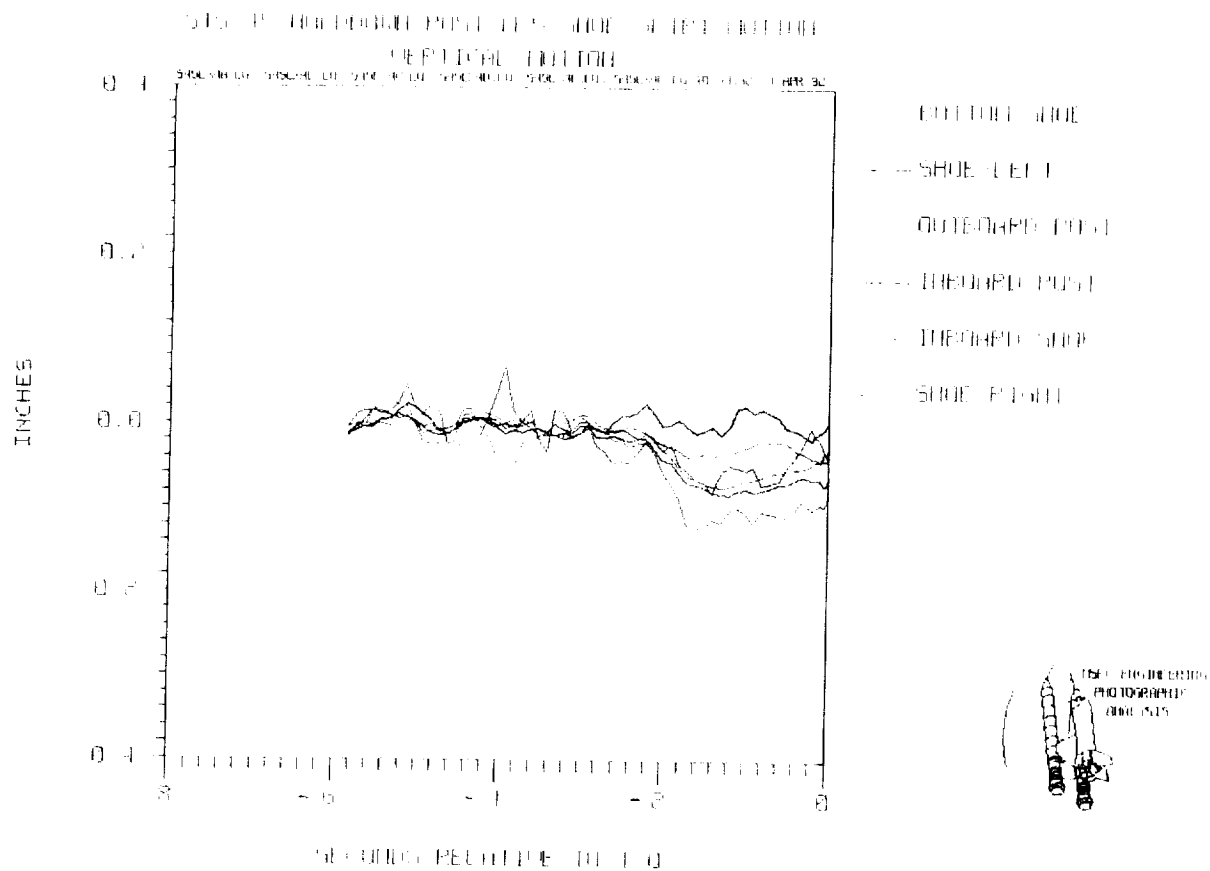


Figure 19

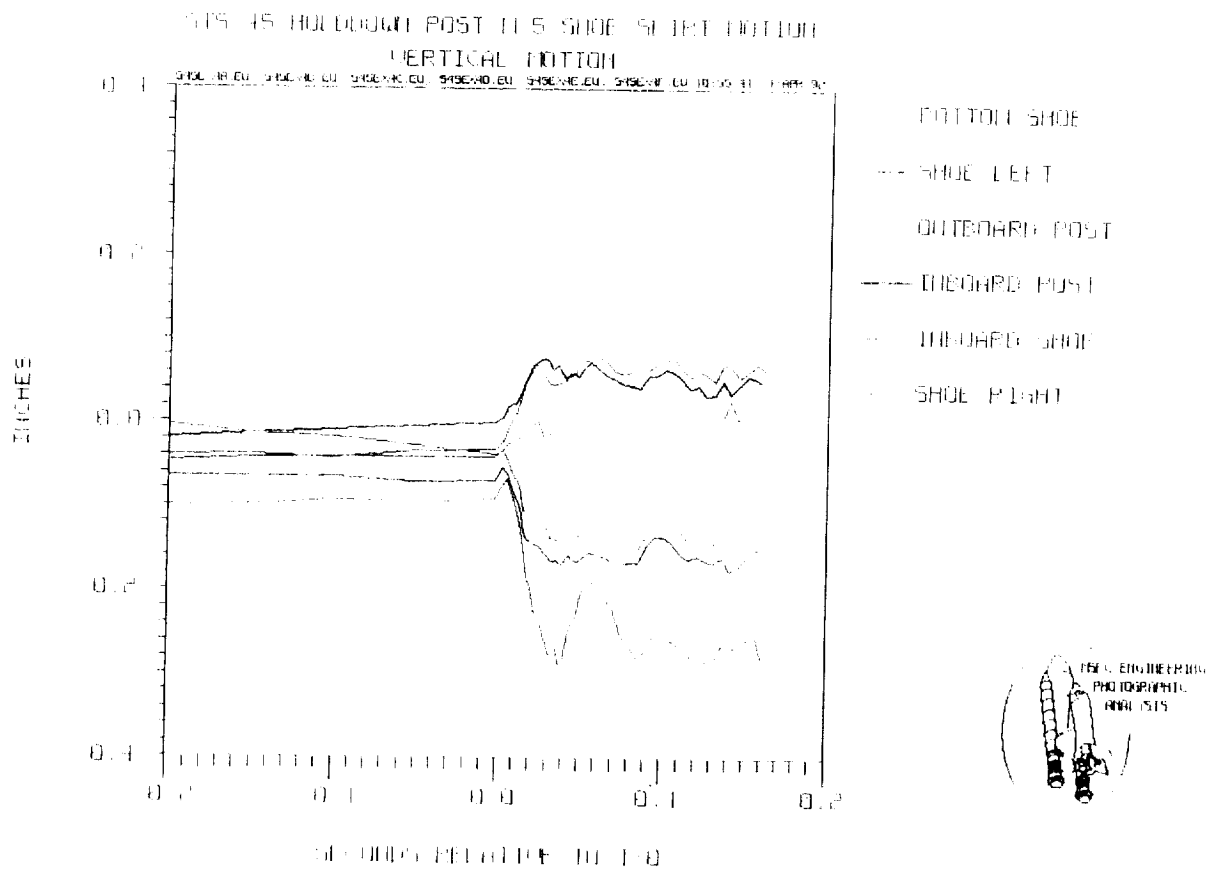
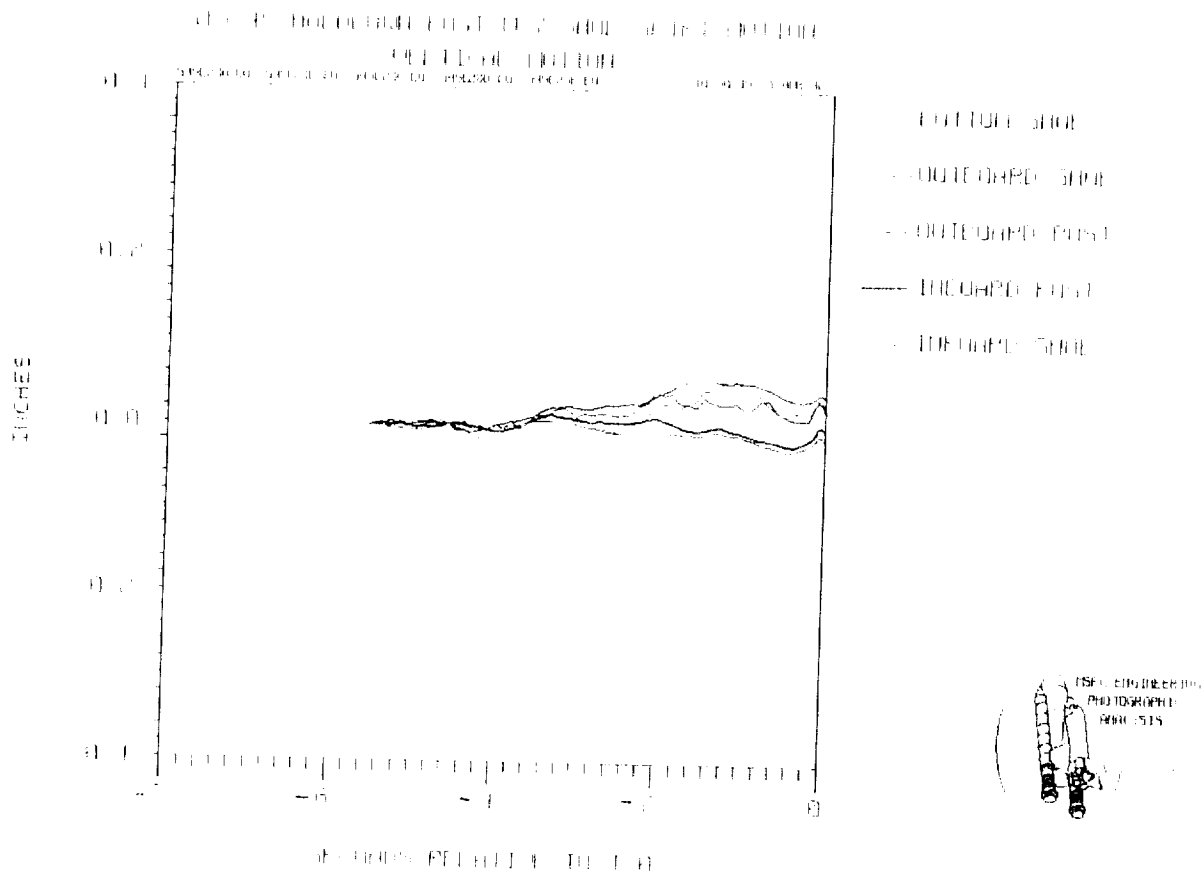


Figure 20



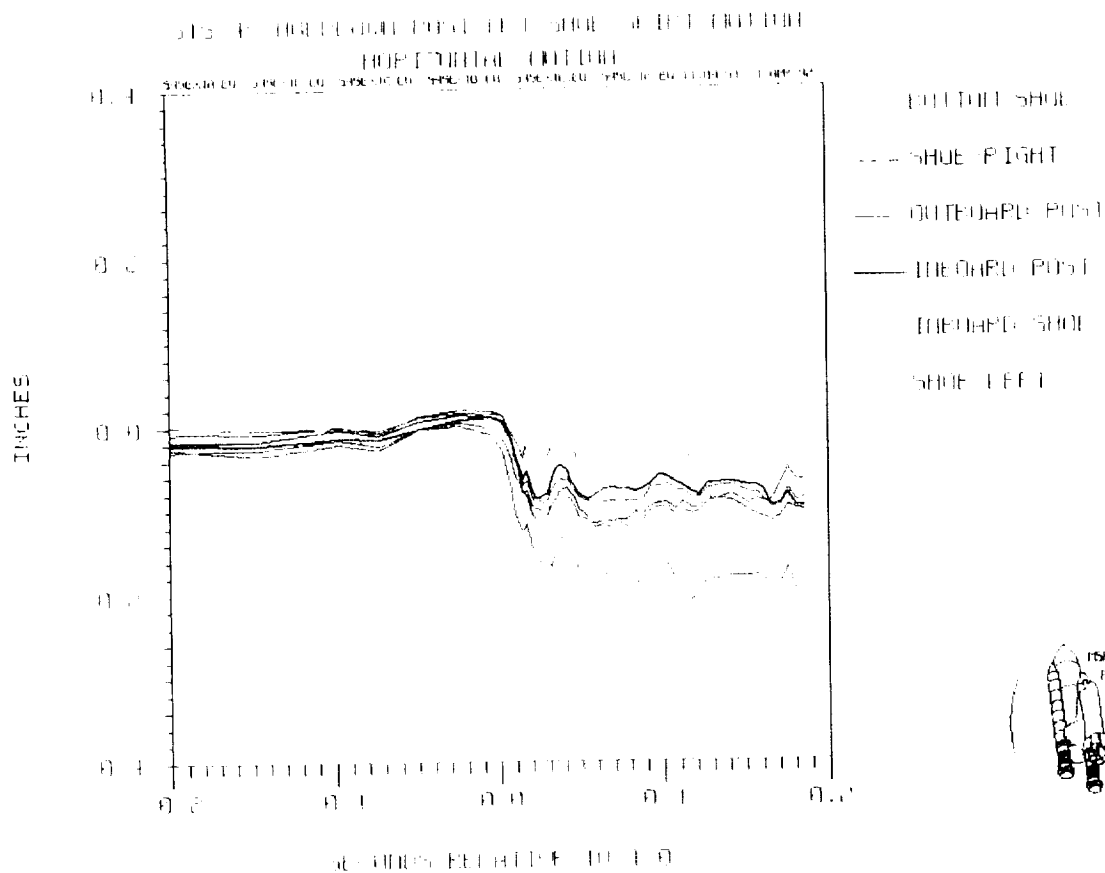


Figure 23

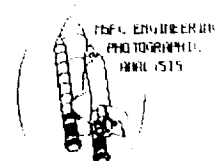
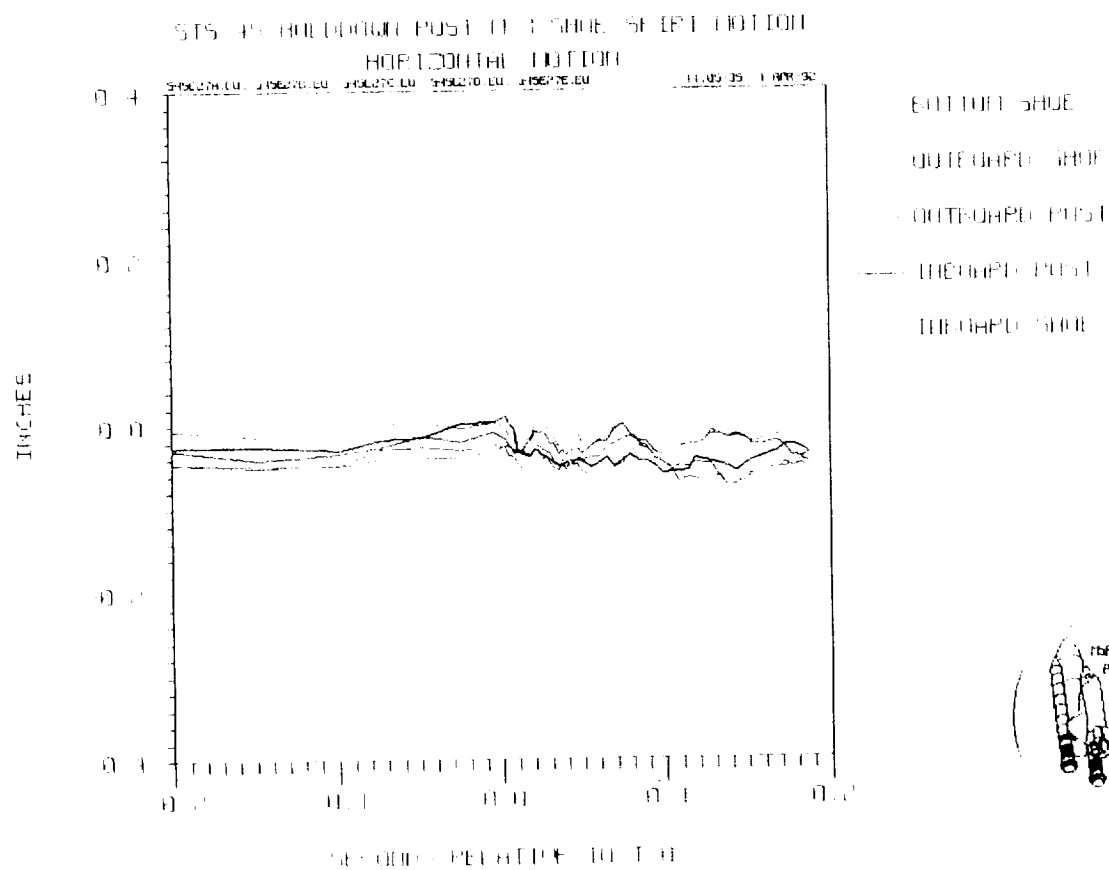


Figure 24

Appendix C. Rockwell Photographic Analysis Summary

Space Transportation Systems Division
Rockwell International Corporation
12214 Lakewood Boulevard
Downey, California 90241



May 4, 1992

In Reply Refer to 92MA2014

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Attention: L. G. Williams (WA)

Contract NAS9-18500, System Integration, Transmittal of the Rockwell Engineering Photographic Analysis Report for the STS-45 Mission.

The System Integration Contractor hereby submits the Engineering Photographic Analysis Summary Report in accordance with the Space Shuttle Program Launch and Landing Photographic Engineering Evaluation Document (NSTS 08244).

Extensive photographic and video coverage was provided and has been evaluated to determine ground and flight performance. Cameras (cine and video) providing this coverage are located on the Launch Complex 39A Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-45 launch conducted on March 24, 1992, at approximately 5:13 am (PST) from the Kennedy Space Center (KSC) and for the landing on April 2, 1992 at KSC (3:23 am PST).

Rockwell received launch films from 85 cameras (62 cine, 23 video) and landing films from 26 cameras (9 cine, 17 video) to support the STS-45 photographic evaluation effort. One film, E220 was not obtained due to camera malfunction.

All ground camera coverage for this mission including coverage on the MLP, FSS and tracking cameras were good. However, due to the accumulation of clouds, many of the tracking video and films reviewed were obstructed after the vehicle went through the cloud cover. This hampered analysis and possible detection of debris and/or anomalies.

Overall, the films showed STS-45 to be a clean flight. Several pieces of ice from the ET/ORB umbilicals were shaken loose at SSME ignition, but no damage to the Orbiter Thermal Protection System (TPS) was apparent. The usual condensation and water vapors were seen at the ET aft dome and the SRB stiffener rings and dissipated after the completion of the roll maneuver. No Vapor was observed in the vicinity of the rudder/speed brake at liftoff. Charring of the ET aft dome and recirculation were visible and normal. Booster Separation Motor (BSM) firing and SRB separation also appeared to be normal.

(Packing Sheet No. DM92-13454)

Nominal performance was seen for the MLP and FSS hardware. FSS deluge water was activated prior to SSME ignition and the MLP rainbirds were activated at approximately 1 second Missions Elapsed Time (MET), as is normal. All blast deflection shields closed prior to direct SRB exhaust plume impingement. Both TSM umbilicals released and retracted as designed. The ET GH2 vent line carrier dropped normally and latched securely with no rebound. No anomalies were identified with the ET/ORB LH₂ umbilical hydrogen dispersal system hardware.

STS-45 was the sixth flight with the optimized attach link in the SRB holddown support post Debris Containment Systems (DCS's). The link is designed to increase the plunger velocity and seating accuracy, while leaving the holddown bolt ejection velocity unchanged. This prevents frangible nut fragments and/or NSI cartridges from falling from the DCS, while not increasing the probability of a holddown bolt hang-up.

Three major or significant events were observed or identified. A disturbance in the lateral acceleration strip chart data at liftoff led Rockwell to suspect there had been a bolt hangup on one of the SRB holddown support posts. Also the crew reported venting of the ET after separation and after landing (during the post landing inspection) two divots were found on the Orbiter right wing leading edge RCC (reinforced carbon-carbon) panel #10. These events and other events noted by the Rockwell film/video users during the review and analysis of the STS-45 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

COMMENTS


1. During liftoff, a disturbance in the lateral acceleration strip chart data at Rockwell-Downey indicated a possible bolt hangup on one of the SRB holddown posts. This was confirmed when film E-7 was reviewed and the post M-4 bolt was seen at hangup at liftoff. The bolt also deflected during liftoff until the aft skirt foot rose sufficiently to release it, causing the bolt to spring back to its original vertical position. This event has been noted on previous missions. No follow-up action has been requested or planned.
2. A potential inflight anomaly was reported by the crew at ET separation. While performing DTO-312 the astronauts observed venting or vapors from the aft disconnects (oxygen or hydrogen) of the ET. After landing, views of the ET after separation from the Orbiter consisted of one 16 mm film and 38 still 70 mm frames (OV-104 was not equipped to carry umbilical cameras). Venting (conical in shape) was seen coming from the LH₂ umbilical area on the 16 mm film only. KSC and MSFC reported that venting was visible in frame #1 of the 70 mm film. A CAD/CAM reconstruction/enhancement of frame #1 (70 mm) provided by MSFC showed the venting coming from the LH₂ umbilical. No evidence of venting or vapors from the ET intertank has been seen on either the 16 mm or 70 mm films. All photographic products available have been reviewed by engineering personnel supporting the investigation. No additional action(s) are currently planned.

3. The landing of STS-45 occurred on runway 33 at KSC. After landing, two significant divots were found on the Orbiter right wing leading edge RCC (reinforced carbon-carbon) panel #10. The divots were down to the first layer of cloth and were 1.9 x 1.6 x 0.17 (deep) inches and 0.8 x 0.7 x 0.2 inches in size. In an effort to determine the source(s) of the damage, 9 landing films, 17 landing video cameras, and selected launch films from 8 perimeter cameras and 5 tracking cameras were reviewed. No anomalies were observed that could be related to the wing damage. Events normally observed on previous flights were seen from these cameras. No additional action(s) are planned.
4. On cameras E-011, E-016 and E-028, a dark piece of debris originates from the stud hole at HDP M-7 and fell aft after liftoff. No follow-up action is planned for this item.
5. A single thin, rope-like piece of debris originates from behind the right RCS stinger and fell aft into the SSME area prior to liftoff. The debris was identified as tape from the RCS and was seen on cameras E-001, E-002, E-003, E-004, E-015, and E-017. It is not considered an issue and no follow-up action is planned.
6. On cameras E-212, E-213, and E-222, a large white piece of debris was noted behind SSME#1 falling aft and split into two pieces after the roll maneuver. This material is probably the two pieces of SSME closeout blanket patch material found near the pad after launch. No follow-up action is required.
7. On cameras KTV-4A, KTV-5A, KTV-13, ET-204, ET-207, ET-208, ET-212, E-204, E-205, E-207, E-208, E-212, E-208, and E-223 three orange pulses were noted in the SRB exhaust plume prior to SRB separation. These observations have been seen on previous missions and are understood at be burning of propellant impurities. It is not considered an issue and no follow-up is planned.
8. A piece of orange debris (possibly baggie material) noted from the LO₂ umbilical area. The debris is entrained in the recirculation flow and falls aft at approximately 23.5 seconds MET. This event was noted on cameras E-212, E-213 and E-222 and is not considered an issue.
9. Several typical events reported on other launches were observed on STS-45. These events are not a concern, but are documented here for information only:
 - Ice debris falling from the ET/Orbiter Umbilical disconnect area.
 - Debris (Pad, insta-foam, Water trough) in the holddown post areas and MLP
 - Butcher paper falling from the RCS
 - Recirculation or expansion of burning gases at the aft end of the SLV
 - Slight TPS erosion on the base heat shield during SSME start-up.
 - Throat plug material which was ejected from the SRB flame duct north of the vehicle at liftoff;
 - Body flap motion during the maximum dynamic pressure (Max-Q) region which appeared to have an amplitude and frequency similar to those of previous missions.

- Charring of ET aft dome.
 - SRB plume brightening, prior to SRB separation.
 - Linear optical distortions, possibly caused by shock waves or ambient meteorological conditions near the vehicle, after the roll maneuver.
 - A Large piece of EPON shim material which debonded from the holddown post M-4 aft skirt foot and fell into the flame duct during liftoff (probably caused by the bolt hang-up which occurred on the same post).
 - Holddown post shoe rotation during liftoff which was observed to be similar to that seen on previous missions.
 - Two RCS jets, R3D and R3R, that were seen to be missing their paper covers prior to launch - an event which was known and waived;
10. Cameras E33 and E41 - OMRSD File IX Vol. 5, Requirement No. DV08P.010 requires an analysis of launch pad film data to verify that the initial ascent clearance separation between the left SRB outer mold line and the falling ET vent umbilical structure does not violate the acceptable margin of safety.
- A qualitative assessment has been conducted and positive clearances between the left SRB and the ET vent umbilical have been verified. The films showed nominal launch pad hardware performance, and no anomalies were observed for the SRB body trajectory.
11. Cameras E7-16 and E27-28 - OMRSD File IX Vol. 5, Requirement No. DV08P.20 requires an analysis of film data of SRM nozzle during liftoff to verify nozzle to holddown post drift clearance.
- A qualitative assessment of the launch films has been completed. No anomalies were observed for the SRM nozzle trajectory and positive clearances between the SRB nozzles and the holddown posts were verified.

This letter is of particular interest to Mr. W. J. Gaylor (VF2) and Mr. R. W. Hautamaki (WE3) at JSC. The Integration Contractors contacts are W. S. Trueman at (310) 922-1200 or R. Ramon at (310) 922-3679.

ROCKWELL INTERNATIONAL
Space Systems Division


J. A. Wolfelt
Chief Engineer
System Integration

RR:vss



Report Documentation Page

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16. Abstract A Debris/Ice/TPS assessment and integrated photographic analysis was conducted for Shuttle Mission STS-45. Debris inspections of the flight elements and launch pad were performed before and after launch. Ice/frost conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and integrated photographic analysis of Shuttle Mission STS-45, and the resulting effect on the Space Shuttle Program.			
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